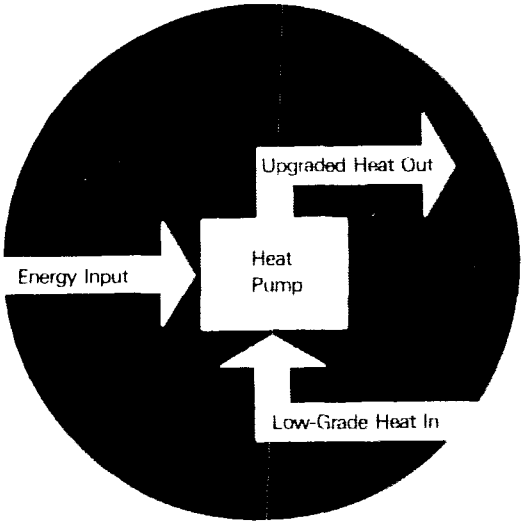
U.S. Heat Pump Research and Development Projects



August 1982

U.S. Department of Energy
Assistant Secretary, Conservation and
Renewable Energy
Office of Buildings Energy R & D

TRP
528

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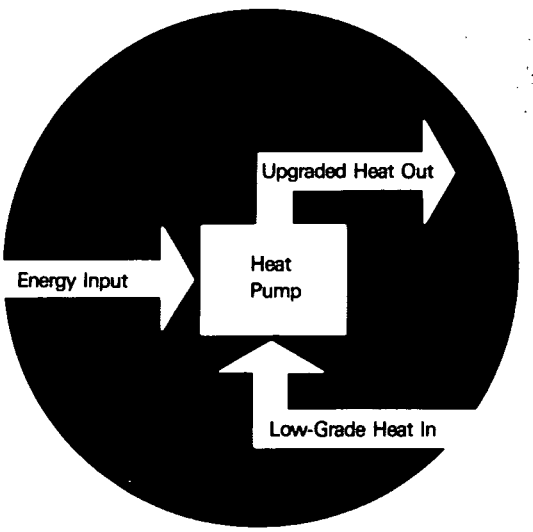
U.S. Heat Pump Research and Development Projects



August 1982

U.S. Department of Energy
Assistant Secretary, Conservation and Renewable Energy
Office of Buildings Energy R & D
Washington, D.C. 20585

FOREWORD

The purpose of this document is to facilitate information exchange on heat pump research and development projects and programs. This report is aimed at individual researchers, technical project monitors and program administrators who need a greater awareness of the scope and type of R&D being carried out in the U. S. on heat pump technologies. The ultimate goal, of course, is to improve program cooperation among sponsoring agencies and to increase technical exchanges between researchers.

This report was prepared through the efforts of the Department of Energy (DOE) Heat Pump Integration Task Force, an ad hoc group formed to coordinate heat pump-related research efforts among the six DOE offices conducting such research within DOE. The Task Force maintains close liaison with the Gas Research Institute and the Electric Power Research Institute which also carry out extensive heat pump R&D programs.

This report would not have been possible without the help of those people who identified projects and obtained complete copies of the project summary forms. For DOE-sponsored projects, key contributors were program managers at each of DOE's National Laboratories:

- John Andrews, Brookhaven National Laboratory
- Fredrick Creswick, Oak Ridge National Laboratory
- Gerson Grossman, Oak Ridge National Laboratory
- Robert Holtz, Argonne National Laboratory
- Michael Wahlig and Albert Heitz, Lawrence Berkeley Laboratory

Substantial support from non-DOE sponsors also made this document truly comprehensive:

- James Calm, Electric Power Research Institute
- Edward Tabb, Gas Research Institute
- Leslie Wright, Gas Research Institute

The assembly and quality control of the finished project summaries was accomplished by Quon Kwan of the Aerospace Corporation, Washington, D.C.

John Ryan, Chairman
DOE Heat Pump Integration
Task Force

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1. INTRODUCTION

The heat pump, a device which moves heat from a region of low temperature to a region of higher temperature, can produce important energy conservation and economic benefits in a wide variety of applications. The potential for achieving significant gains in these benefits by advancing the technologies of heat pumps has been recognized by private and government groups sponsoring energy research and development.

Several offices within the Department of Energy are sponsoring heat pump programs for specific applications or for specific technologies. These programs include industrial waste heat utilization and process heat production, solar energy utilization, building heating, cooling and water heating, and district heating, using a wide variety of technical approaches. The Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI) likewise are sponsoring significant programs of research and development in their respective areas of interest in many of the same areas as DOE.

This report is a compilation of project summary forms which provide descriptive data about individual R&D projects. Projects sponsored by DOE, EPRI, GRI and others are included for all the applications mentioned above. The document is intended to include all heat pump projects for which results are publicly available.

Given the widely-recognized potential of heat pump technologies and the number of organizations that sponsor R&D in the area, it may not be surprising that there are 153 research projects summarized in this document. (This includes both current projects and projects completed within the last 3 to 4 years.)

These projects have a total budget in excess of $100 million. The table below provides more detailed budget data for the major technology categories used in this document.

Summary of Heat Pump Budget Data

Heat Pump Technology	Projects Reporting Budget Data Total Funding	No. of Projects	Total Projects
Electric motor driven	$19,844K	46	55
air-source	5,181	5	10
solar-assisted	5,279	16	16
ground/water source	4,321	15	19
ACES	5,063	10	10
Generic Rankine Technology	3,352	4	9
Heat Engine Actuated	$55,081K	26	29
non-Rankine	20,321	11	14
Rankine	34,760	15	15
Absorption & Chemical	19,563	31	34
Cross-Cutting and Other	10,604	22	26
Totals	$108,444K	129	153

In the international arena heat pump technologies are equally an active target of sponsored research work. Significant individual government-sponsored programs are being carried out in West Germany, Sweden, Great Britain and France. In addition, the Commission on the European Communities sponsors an active multi-lateral R&D program in heat pumps. Jointly-sponsored government research projects are also developed and coordinated through the International Energy Agency's Executive Committee on Advanced Heat Pump Systems. This group is in the process of establishing a Heat Pump Data Center which should, in the near future, be able to provide project summary information on worldwide research efforts.

2. DEFINITION OF A HEAT PUMP PROJECT

An attempt has been made to be as broad as possible in defining what type of systems constitute a heat pump for reporting in this document. The most familiar heat pumps are those which employ an externally-driven, reverse Rankine refrigeration cycle operating in a continuous mode in a closed cycle between heat source and sink. In addition to these systems, of which there are many variations, this report also includes open cycle types, noncontinuous operating systems, non-Rankine cycles, absorption-driven systems and "heat transformers" as well as heat pumps. A wide variety of applications are covered in the projects summarized: building heating and cooling, industrial process heat production and solar energy utilization.

To be classed as a heat pump system for the purposes of this report however, it is necessary that the upgrading of thermal energy be the main purpose of the system. Generally, it is necessary that some type of thermodynamic refrigeration cycle be involved which has a heat engine analogy. However, thermoelectric or magnetic approaches would be classed as heat pumps for this report. Specifically excluded from this report are systems which have as their main purpose the removal of water vapor from an air stream by means of desiccation.

No rigorous attempt was made to identify all projects dealing with generic component technologies of potential use in heat pump systems, e.g. generic heat transfer studies, heat engine or combustion developments or generic compressor development efforts. Where identified generic projects were known to have a strong application potential to heat pumps or where they are being carried out as part of a sponsoring group's heat pump program, they are included.

Only projects which are research oriented are included in this report. Research projects are those intended to provide information which, in some way, will advance the technological status of heat pumps or the general state of knowledge about heat pumps. Heat pump installations which are subsidized in some way, but which have as their main goal conservation of energy rather than research, are not included.

An effort was made to include every project which existed in the last 3 years (i.e., 1979 through 1981). Older projects were sought was well but there was no rigorous effort to be all inclusive for the earlier projects. Every heat pump project for which a project summary form was submitted, however, is included in the report. Apology is made for any projects which have been overlooked; if these projects are brought to DOE's attention, they can be included in future updates to this report.

There is substantial self-funded heat pump research work going on in the private sector. Specifically excluded from this report are projects which are wholly privately funded and for which the results are regarded as proprietary. Some private sector work, namely that carried out by the Gas Research Institute and the Electric Power Research Institute, is included.

3. ORGANIZATIONS SUPPORTING R&D ON HEAT PUMPS

Those organizations sponsoring the majority of publicly available research in heat pumps are described below in sections 3.1 through 3.3. Other organizations sponsoring research projects included in this document are listed in section 3.4.

3.1 U.S. Department of Energy

1000 Independence Avenue, SW
Washington, DC 20585
(202) 252-5000

The Department of Energy (DOE) provides the framework for a comprehensive and balanced national energy plan through the coordination and administration of the energy functions of the Federal Government. The Department is responsible for the research, development, and demonstration of energy technology; the marketing of Federal power; energy conservation; the nuclear weapons program; regulation of energy production and use; and a central energy data collection and analysis program.

3.2 Electric Power Research Institute

3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94303

The Electric Research Power Institute (EPRI) was founded in 1972 by all sectors of the Nation's electric utility industry to develop and administer a coordinated national electric power research and development program. Through selection, funding, and management of research projects conducted by contracting organizations, EPRI promotes the development of new and improved technologies to help the electric utility industry meet present and future electric energy needs in environmentally and economically acceptable ways.

The primary areas of EPRI's research are advanced power systems, coal combustion systems, energy management and utilization, nuclear power, electrical systems, and energy analysis and environment.

EPRI's funding comes from over 600 electric utilities across the country, representing about 70 percent of the Nation's electric power service. In 1982, members were contributing the equivalent of 0.236 mills ($0.000236) per kilowatt hour of their 1980 consumer sales toward this program.

3.3 The Gas Research Institute

8600 Bryn Mawr Avenue
Chicago, IL 60631
(312) 399-8100

GRI is a not-for-profit, scientific research organization that plans, manages, and finances a coordinated R&D program in gaseous fuels and their use.

GRI was founded in 1976 in response to gas industry and gas consumer needs for assured, long-term gas supplies, reliable delivery, and efficient appliances and equipment. It was apparent that gas would continue to play a major role in supplying the Nation's energy and that new supply, distribution, and utilization technologies should be developed under a strong national commitment. The Gas industry leaders decided that a single organization should direct this R&D function to

facilitate the acquisition of sufficient funds for a comprehensive program.

Support for GRI's R&D program comes through a funding unit applied to the gas volumes sold by its members. In 1982, the funding unit is 7.2 mills per thousand cubic feet of gas. Currently there are 195 member companies from interstate pipelines, distribution companies, and publicly owned municipal utilities. In addition, ten foreign organizations are associate members.

GRI's research program consists of seven major areas: natural gas supply, substitute natural gas supply, residential/commercial energy systems, industrial utilization, transport and storage, environment and safety, and basic research.

3. 4. Other Organizations supporting projects listed in this document are:

National Bureau of Standards
Washington, DC 20234

New York State Energy Research and Development Authority
Empire State Plaza
Albany, NY 12223

National Science Foundation
1800 G Street, NW
Washington, DC 20550

4. SUMMARY FORM AND REPORT ORGANIZATION

4.1 Description of Summary Form

A blank copy of the heat pump project summary form is shown in reduced appearance on the next page. (The actual form is a mat measuring 11x17 inches; the large size allows for the maximum inclusion of typewritten information on a camera-ready sheet which can be reduced 65 percent.)

The first item on the form is the project title. The project title is intended to be terse yet sufficiently informative to allow one to identify immediately a general category into which the project falls, e.g. hardware development as opposed to performance monitoring or electric versus nonelectric as the prime mover. The project title used here does not necessarily coincide with the actual contractual title because it could be an element or subelement of a larger project, adopted from the title of a final report or paper, or modified after the project had been initiated.

The form contains a space for the name(s) of the principal investigator(s), the responsible organization, its address, and the telephone number of the principal investigator. A space is available for the corresponding information about a subcontractor to the responsible organization if a subcontract was awarded for some major aspect of the project.

Project funding is given with also the source(s) and level(s). In a number of cases, more than one source is identified. In some cases, when it was not possible for the principal investigator to segregate the funding for the project stated from other projects that were cofunded, "not available" appears. Funding information has not been included for EPRI sponsored projects. Instead, this space shows the responsible EPRI project manager; this is given in consistency with EPRI practice.

To the right of funding information are the contractual details: the contract number, the agency awarding or having program management responsibility over the contract, and the contract period. In most cases where the contract was awarded over 3 years ago, a year in lieu of a month and year will be given for the contract initiation date because of the difficulty of obtaining the precise date. The contract number is particularly useful for correlating these project summaries with published reports or other project compilations which often provide contract numbers.

The project objectives are provided in the next box and the project description and status in the penultimate box. An attempt was made to provide a brief statement of the essential and rudimentary conclusions about a project that could be meaninfully used by another researcher, policy maker, program planner, or project manager. If the project was still on-going at the time, then a brief statement concerning the milestones attained and the major activities to be pursued or the obstacles to be attacked was provided.

The last box gives design specifications of the eventual heat pump hardware. Completion of this box was required for all hardware development projects and requested for any project which entailed performance monitoring, implementation, demonstration, or testing of a single heat pump. The design specifications include thermal output (or cooling capacity) in Btu/hr, the working fluid, the source from which heat is to be extracted, the sink or medium to which the heat is to be delivered, the condenser and evaporator temperatures (^{o}F), and the steady-state coefficient of performance at the design temperature.

PROJECT SUMMARY

PROJECT TITLE:

PRIN. INVESTIGATOR:

ORGANIZATION:

ADDRESS:

TELEPHONE NO.:( )

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $_____

SOURCE(S)	LEVEL (%)

CONTRACT NO.:

CONTRACT AGENCY:

CONTRACT PERIOD:

FROM_____ THROUGH_____

PROJECT OBJECTIVES:

PROJECT DESCRIPTION AND STATUS:

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

4.2 Report Organization

The project summary forms have been arranged into technology groups according to the type of heat pump cycle, drive system and/or heat source. A number of multi-disciplinary or cross-cutting projects are being pursued and a group is established for these projects as well.

There is no duplication of project summaries in this report, therefore, projects which address more than one major technical area are usually assigned to the cross-cutting group. Some arbitrariness is involved in group assignments; particularly in the subgroups dealing with electric-drive systems. It is hoped that the classification scheme will, however, help to expedite location of projects of interest.

Within each section (technology group) of this report, the project summaries are ordered by contract start date in reverse chronological sequence.

SECTION 5

PROJECTS WITH ELECTRIC MOTOR-DRIVEN REVERSED RANKINE CYCLES

(55 PROJECTS)

SUB-SECTIONS :

5.1 AIR HEAT SOURCE

5.2 SOLAR ASSISTED

5.3 GROUND OR WATER SOURCE

5.4 ANNUAL CYCLE ENERGY SYSTEM (ACES)

PROJECT SUMMARY

PROJECT TITLE:

MONITORING OF CENTRAL AND ROOM HEAT PUMPS

PRIN. INVESTIGATOR: Charles E. Bullock

ORGANIZATION: Carrier Corporation

ADDRESS: Research Division
P.O. Box 4808
Syracuse, NY 13221

TELEPHONE NO.: (315) 432-6204

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:

James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94402
(415) 855-8949

CONTRACT NO.: RP2033-9

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 2/10/82 **THROUGH** 8/31/83

PROJECT OBJECTIVES:

This project will collect, analyze, and report field operating data and measure critical aspects of heat pump performance including heating and cooling energy delivered, energy consumed, operating times, and other key parameters on daily, monthly, and seasonal bases. Peak power demand characteristics will be reported. The relative effects of equipment sizing and local climate will also be addressed.

PROJECT DESCRIPTION AND STATUS:

Field monitoring of unitary, air-source heat pumps in both the heating and cooling modes is the focus of this project. Thirteen central and room heat pumps in a variety of climatic conditions are under study. The residential, central systems involved include:

- Dual-split heat pump with electric supplemental heat (Dallas, TX),
- Dual-split hybrid with a gas furnace (Liverpool, NY),
- Dual-split hybrid with an oil-fired furnace (Syracuse, NY),
- Dual-split hydronic hybrid in series with an oil-fired boiler (Central Square, NY),
- Dual-split hydronic hybrid in parallel with an oil-fired boiler (Lake Placid, NY),
- Triple-split heat pump with a desuperheater water heater (Kingsport, TN),
- Triple-split with two single-speed compressors (Minneapolis, MN), and
- Triple-split with one dual-speed compressor (Batchtown, IL).

The room heat pumps include residential and commercial systems in:

- Room heat pump (Syracuse, NY),
- Room heat pump (Boston, MA),
- Room heat pump (Baltimore, MD),
- Packaged terminal heat pump (St. Louis, MO), and
- Packaged terminal heat pump (Augusta, GA).

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

HEAT PUMP WATER HEATERS

PRIN. INVESTIGATOR: Morton H. Blatt

ORGANIZATION: Science Applications, Inc.
Energy Systems and Conservation Division

ADDRESS: 1200 Prospect Street
P.O. Box 2351
La Jolla, CA 92038

TELEPHONE NO.: (714) 454-3811

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP2033-5

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 9/1/81 **THROUGH** 6/30/82

PROJECT OBJECTIVES:

The primary purposes of this project are to evaluate the experience of electric utilities with heat pump water heaters and to develop a guide on them for utility use. The guide will address the technology, its application and economics, and experimental techniques for further tests.

PROJECT DESCRIPTION AND STATUS:

This work includes an analysis of heat pump water heater technology, a review of utility field test experience and experimental designs, and an assessment of utility impacts of heat pump water heater use. Identification of further research requirements is also included. The technologies to be addressed include:

- Packaged heat pump water heaters,
- Unitary, split system heat pump water heaters,
- Retrofit assemblies to convert electric resistance heaters to heat pump water heaters, and
- Desuperheater water heaters.

Many utilities have already tested various heat pump water heaters. Twenty of these tests including 85 units (plus 15 aborted retrofit tests) were documented in a DOE sponsored study by their manufacturer. This project will comprehensively address these and other tests including products of various manufacturers, test objectives, and experimental designs.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

MONITORING OF AIR-TO-AIR MULTIZONE HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: J. Patrick Quinn

ORGANIZATION: International Systems Corporation

ADDRESS: 1754 Technology Drive, Suite 116
San Jose, CA 95110

TELEPHONE NO.: (408) 280-6002

SUBCONTRACTOR: Sierra Pacific Power Company
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 355-8949

CONTRACT NO.: RP1201-15

CONTRACT AGENCY:
Electric Power Research Institute (EPRI).

CONTRACT PERIOD:

FROM 11/12/80 **THROUGH** 7/28/82

PROJECT OBJECTIVES:

The objectives of this project are to:

- Acquire performance data on residential multizone heat pumps,
- Monitor whether occupants utilize zonal control,
- Examine the impacts of zonal demand diversity on electrical power demand, and
- Compare energy-use of multizone heat pumps to that of zoned resistance heating and other alternative systems.

PROJECT DESCRIPTION AND STATUS:

Two multizone heat pumps are being monitored in residences located in Reno, Nevada. Each system uses a single, outdoor, compressor and heat exchanger unit serving five separate indoor heat exchangers. The indoor units are individually controlled, thereby enabling heating and cooling on a room-by-room or zone-by-zone basis. Unoccupied areas may be separately shut-off or heated to reduced temperatures. Each indoor unit includes a supplemental resistance heater for use during defrost of the outdoor unit and when additional capacity is needed. Because the indoor units are connected to the outdoor unit by refrigerant piping, no ducts are required. Such systems can be installed in both new and retrofit applications. Although common in Japan, they are just being introduced in the U.S.

Sierra Pacific Power Company is assisting in the data analysis and providing limited field support.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

Not applicable

PROJECT SUMMARY

PROJECT TITLE:

FIELD TEST AND ANALYSIS OF SINGLE-SPEED HEAT PUMP SEASONAL PERFORMANCE

PRIN. INVESTIGATOR: Heinz Jaster

ORGANIZATION: General Electric Company
Corporate Research and Development

ADDRESS: P.O. Box 43, Building 37
Schenectady, NY 12301

TELEPHONE NO.: (518) 385-0162

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP1495-1

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 10/29/80 **THROUGH** 7/31/82

PROJECT OBJECTIVES:

This project seeks to provide both quantitative data on and algorithms for accurate prediction of performance of conventional heat pumps.

PROJECT DESCRIPTION AND STATUS:

The project addresses performance of conventional residential heat pumps. Included are:

- Laboratory tests of transient heat pump performance,
- Field measurement of heat pump performance in nine occupied houses, and
- Development of analytical procedures for prediction of seasonal heating efficiency of heat pumps.

Nine single-family residences in three differing climates are equipped with 2.5 ton, single-speed, air-to-air heat pumps with auxiliary electric-resistance heat. These systems have been instrumented to measure capacity, performance, power (demand), and energy consumption of major components and the total systems. Seasonal and representative performance are being analyzed including accounting for cycling and defrost effects. The results are being compared against DOE and industry test and rating procedures.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: IMPROVEMENT ON METHODS OF TESTING CENTRAL AIR CONDITIONERS AND HEAT PUMPS

PRIN. INVESTIGATOR: DAVID TREE

ORGANIZATION: HERRICK LABS

ADDRESS: Purdue University
West Lafayette, IN 47901

TELEPHONE NO.: (317) 494-2138

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $350,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: CS23337

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM 01/09/80 **THROUGH** 09/31/82

PROJECT OBJECTIVES: This procurement involves research work in the area of reducing the test requirements for central air conditioners and heat pumps. The work including developing a data base upon which mathematical model of the performance of the heat exchangers will be developed; conduct of tests on a central air conditioner previously tested by the National Bureau of Standards as part of a round-robin test program; and research on refrigerant migration.

PROJECT DESCRIPTION AND STATUS: Contractor has nearly completed efforts on developing a mathematical simulation model of heat exchangers which is directed at identifying what happens in air conditioners and heat pumps in the cooling mode inside the evaporator at compressor start-up.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

MONITORING OF IMPROVED AIR-SOURCE HEAT PUMPS

PRIN. INVESTIGATOR: Charles E. Bullock

ORGANIZATION: Carrier Corporation
Research Division

ADDRESS: P.O. Box 4808
Syracuse, NY 13221

TELEPHONE NO.: (315) 432-6204

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:

James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94402
(415) 855-8949

CONTRACT NO.: RP789-3

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 12/17/79 **THROUGH** 7/31/82

PROJECT OBJECTIVES:

This project will collect, analyze, and report field operating data and measure critical aspects of heat pump performance including heating and cooling energy delivered, energy consumed, operating times and other key parameters on daily, monthly, and seasonal bases. Peak power demand characteristics will also be reported. The relative effects of equipment sizing and local climate will also be addressed.

PROJECT DESCRIPTION AND STATUS:

Field monitoring of unitary, residential, air source heat pumps in both the heating and cooling modes is the focus of this project. Seven split-system installations representing a variety of climatic conditions are under study. The heat pumps involved include:

- A two-piece system with an electric auxiliary heater,
- A two-piece hybrid with a gas furnace,
- A two-piece hydronic hybrid with an oil-fired boiler,
- A three-piece system with a desuperheater water heater,
- Two three-piece systems with dual compressors, and
- A three-piece system with a dual-speed compressor.

Data collection was completed in December 1981 and the remaining effort will focus on analysis and reporting.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

ADVANCED ELECTRIC RESIDENTIAL HEAT PUMP

PRIN. INVESTIGATOR: Stephen E. Veyo

ORGANIZATION: Westinghouse Electric Corporation

ADDRESS: Research and Development Center
1310 Beulah Road
Pittsburgh, PA 15235

TELEPHONE NO.: (412) 256-7638

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 3,426,534

SOURCE(S)	LEVEL (%)
Department of Energy	72.96
Westinghouse Electric Corp.	27.04

CONTRACT NO.: 86X-24712C

CONTRACT AGENCY: Oak Ridge National Laboratory

CONTRACT PERIOD:

FROM October 1979 **THROUGH** December 1982

PROJECT OBJECTIVES:

The Advanced Electric Residential Heat Pump research and development program has as its objective the development of a preproduction prototype, commercially and economically viable advanced heat pump that can provide satisfying performance with an annual energy efficiency at least 20 percent better than the most efficient units available in the market place in early 1979.

PROJECT DESCRIPTION AND STATUS:

The heat pump concept that Westinghouse is developing uses the well known vapor compression refrigeration cycle with R22 as the working fluid. In order to achieve the target efficiency an improved reciprocating compressor with modulatable capacity is being developed along with higher efficiency air movers, a breadboard microprocessor based control system and higher effectiveness heat exchangers. The relative proportions of the compressor, blower, fan and heat exchangers are specified through system optimization to minimize annual ownership cost while constrained to provide comfort. The key to the potential commercial success of this system is the development of low cost compressor capacity modulation means.

A compressor has been developed that uses an eccentric cam between crank pin and connecting rod to change the stroke of the piston upon a reversal in the direction of crankshaft rotation. The efficiency of this compressor is comparable to the best available while the ratio of minimum to maximum capacity can be selected as a parameter of optimization. The incremental cost of this compressor is estimated to be one third that of the compressor with two speed drive motor. An indoor blower 50 percent more efficient and an outdoor fan twice as efficient as current practice have been designed, built and tested. A breadboard system has been built and is being tested to verify our analytical performance estimates and to develop the control software. A dual stroke compressor system has been optimized for DOE Region V. The estimated performance exceeds our target in DOE climate regions II, III, IV and V and the estimated installed price is approximately 5 percent less than the heat pump of comparison. It is estimated that the Westinghouse/DOE advanced heat pump will yield a HSPF of 8.0 and a SEER of 11.23 in Minneapolis and an HSPF of 9.5 and a SEER of 11.33 in Nashville. Analysis projects the 1990 market to be greater than 680,000 units.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 48000 (heating) @ 47°F

WORKING FLUID/HEAT SOURCE/HEAT SINK: R22/Air/Air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 70/47 (Heating); 95/80 DB, 67 WB (cooling) inlet air conditions

STEADY-STATE C. O. P. AT DESIGN TEMP.: Heating: Hi = 3.6; Lo = 3.8; Cooling: Hi = 2.7, Lo = 3.4

PROJECT SUMMARY

PROJECT TITLE: TECHNICAL SUPPORT IN EVALUATION OF CENTRAL AIR CONDITIONER AND HEAT PUMP PERFORMANCE

PRIN. INVESTIGATOR: MORT BLATT

ORGANIZATION: SCIENCE APPLICATIONS, INC.

ADDRESS: P.O. Box 2351
LaJolla, CA 92038

TELEPHONE NO.: (714) 454-3811

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ part of $400,000

SOURCE(S)	LEVEL (%)
DOE	100%

CONTRACT NO.: CS10757

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM 03/79 **THROUGH** 06/82

PROJECT OBJECTIVES: Provide technical support in seasonal performance modeling of central air conditioners and heat pumps.

PROJECT DESCRIPTION AND STATUS: Contractor has completed an evaluation of heat pump defrost performance and has nearly completed seasonal performance and component balance modeling of central air conditioners and heat pumps.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DEMONSTRATION OF A HEAT PUMP WATER HEATER

PRIN. INVESTIGATOR: ROBERT P. BLEVINS

ORGANIZATION: ENERGY UTILIZATION SYSTEMS, INC.

ADDRESS: 365 PLUM INDUSTRIAL COURT
PITTSBURGH, PA 15239

TELEPHONE NO.: (412) 325-2820

SUBCONTRACTOR: (if applicable) NOT APPLICABLE

TOTAL FUNDING: $ 737,735

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	75%
EUS AND VARIOUS ELECTRIC UTILITIES	25%

CONTRACT NO.: SUBCONTRACT NO. 7321

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM AUGUST 1978 **THROUGH** JUNE 1981

PROJECT OBJECTIVES: The objective of this project is to demonstrate the reliability and operating efficiency of a residential heat pump water heater by installing 85 units in climatically dispersed single-family homes and monitoring these installations for a period of one year.

PROJECT DESCRIPTION AND STATUS: The present project is a continuation of an R&D effort carried out by Energy Utilization Systems under the sponsorship of the U.S. Department of Energy. It involves the field demonstration of an air-to-water heat pump water heater designed for residential applications. A total of 85 units were installed in single-family homes located in the service territories of 20 climatically dispersed electric utilities. Utility personnel collected operating data and forwarded it to EUS on a monthly basis. These data were then analyzed and a monthly COP was calculated for each unit.

The monitoring phase of the project was concluded in December 1980. Results show an average COP of 1.93, confirming the units can save about half the energy that would be used by resistance-type water heaters for many locations. The project final report is now being written and is expected to be submitted to ORNL in May 1981.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 7000 (mean heating output - 140°F)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-12/air/water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 55° to 140°F/70°F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 2.1

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF CENTRAL AIR CONDITIONER AND HEAT PUMP TEST PROCEDURE

PRIN. INVESTIGATOR: DAVID DIDION

ORGANIZATION: NATIONAL BUREAU OF STANDARDS

ADDRESS: Washington, DC 20234

TELEPHONE NO.: (301) 921-2994

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 267,000 (FY '82)

SOURCE(S)	LEVEL (%)
DOE	100%

CONTRACT NO.: IAA No. EA-77-01-6010

CONTRACT AGENCY: DOE

CONTRACT PERIOD: Continuing

FROM _____ **THROUGH** _____

PROJECT OBJECTIVES: To develop an equitable testing and rating procedure for determining the seasonal energy performance of central residential heat pumps and air conditioners.

PROJECT DESCRIPTION AND STATUS: The approach will primarily focus on a laboratory and theoretical study towards providing an alternative to the current procedure's most pressing problem, the cyclic testing burden.

The alternative approach to be studied this fiscal year (FY 82) will be that of a simple time constant characterization of the unit. This characterization will require design data of the equipment (size and weight of indoor coil) and a measure of the mass flow of the off cycle refrigerant migration. It is possible that the degradation value obtained in this manner will be somewhat more severe (possibly 1 or 2 percentage points) than the current cyclic tests indicate; but it is also expected that for rating purposes the industry will accept a minor penalty if it meant an increase in repeatability accuracy and a decrease in testing burden. This latter point being addressed by the fact that the time constant approach will require only a start-up and a shut-down test attached to either end of one of the steady-state tests, rather than a full set of cyclic tests.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: TECHNICAL SUPPORT - SOLAR ASSISTED HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: JOHN W. ANDREWS

ORGANIZATION: BROOKHAVEN NATIONAL LABORATORY

ADDRESS: BUILDING 701
UPTON, NEW YORK 11973

TELEPHONE NO.: (516) 282-7726

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 150,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC02-76CH00016

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD: (CURRENT FISCAL YEAR)

FROM OCTOBER, 1980 **THROUGH** SEPTEMBER, 1981

PROJECT OBJECTIVES: The purpose of the project is to provide technical and program planning assistance to the Active Solar Heating and Cooling Division of DOE in connection with the development of energy conserving and cost effective solar assisted heat pump systems.

PROJECT DESCRIPTION AND STATUS: In order to provide a system which meets the technical and economic constraints, the following elements are required:

High efficiency heat pump hardware with performance characteristics tuned to the solar application;
Low cost storage and an available alternate heat source/sink to supplement the solar energy source;
Low cost means for collecting the solar energy in a form best suited to the system configuration.

A reservoir of technical expertise is required to enable program goals in each of these areas to be defined and attained. These activities fall into three categories, which progress to increasingly active roles in the overall program. These categories are contract monitoring, technical support, and program planning.

In addition, selected systems analysis tasks have been carried out, the outcomes of which have significantly affected the direction of the program. Promising system configurations have been identified in each of two general categories - those which use the ground as heat source/sink but not as storage for actively collected solar energy, and those which do use the ground as an active storage element.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: A SECOND GENERATION SOLAR ASSISTED HEAT PUMP SYSTEM

PRIN. INVESTIGATOR: G. W. "DUSTY" RHODES

ORGANIZATION: FAFCO, INCORPORATED

ADDRESS: 235 CONSTITUTION AVENUE
MENLO PARK, CALIFORNIA 94025

TELEPHONE NO.: (415) 321-3650

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $131,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-80CS30224

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JULY, 1980 **THROUGH** SEPTEMBER, 1981

PROJECT OBJECTIVES: To determine the performance analysis, definition and design criteria of plastic collectors for use with heat pump; to collect data and performance analysis of ground coupled heat exchanger configurations; and, to conduct commercialization and marketing analysis.

PROJECT DESCRIPTION AND STATUS: The thermal performance of the proposed solar collector configuration options will be analyzed using computer models. The design criteria for the solar collector and system components will be developed. Operating requirements and conditions determined by the system performance analysis will be the primary basis for setting design criteria for the solar collector and systems components. Ground temperature data and heat flow data will be collected. Pertinent data from other researchers will be utilized. Ground coupling data reduction and analysis will be performed. Useful equipment and system sizing criteria will be established. Also, criteria and a plan for widespread commercial system acceptance will be developed.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: EVALUATION OF DEMONSTRATION PROGRAM FOR USEFUL SOLAR HEAT PUMP PERFORMANCE

PRIN. INVESTIGATOR: JERRY ALCONE

ORGANIZATION: SCIENCE APPLICATIONS, INCORPORATED

ADDRESS: 200 LOMAS NORTH WEST
SUITE 600
ALBUQUERQUE, NM 87102

TELEPHONE NO.: (505) 247-0381

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 66,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: SERI-XP-0-9208-1

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM APRIL, 1980 **THROUGH** OCTOBER, 1980

PROJECT OBJECTIVES: To evaluate heat pump experiment and demonstration sites to assess thermal, economic and reliability behavior of the systems; to analyze existing solar assisted heat pump (SAHP) systems to generate experimental data which can be used to substantiate systems analyses being performed in FY 79 and FY 80; and, to identify areas for future development emphasis in the heat pump program.

PROJECT DESCRIPTION AND STATUS: Potential sites will be identified for data collection and analysis. After site analysis criteria are defined, several operating systems will be selected and their performance data reviewed. Existing analyses will be reviewed and standards will be defined for comparing systems. The selected systems will be analyzed according to these standards and a position paper will be developed for DOE summarizing the status of SAHP systems and recommending future efforts.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SYSTEMS ANALYSIS OF SOLAR ASSISTED HEAT PUMP GROUND COUPLED STORAGE AND DUAL SOURCE STRATEGIES

PRIN. INVESTIGATOR: JEFFREY MOREHOUSE

ORGANIZATION: SCIENCE APPLICATIONS, INCORPORATED (SAI)

ADDRESS: 1710 GOODRIDGE DRIVE
MCLEAN, VA 22102

TELEPHONE NO.: (703) 827-4915

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 109,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: SERI-XP-9-8288-1

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM OCTOBER, 1979 **THROUGH** MARCH, 1980

PROJECT OBJECTIVES: To evaluate the performance and economic advantages to solar assisted heat pumps (SAHP) of ground-coupled storage and dual-source strategies.

PROJECT DESCRIPTION AND STATUS: This study extends the Solar Assisted Heat Pump Comparative Analysis done by SAI in FY 79 by using the same baseline residential systems and adding ground-coupled storage. Thermal and economic performance of the systems with and without ground-coupling is compared. A short study to bracket the performance/economics improvement that could be obtained using a dual-source strategy is included.

The previous studies of series and parallel SAHP systems are extended by performing sensitivity analysis on engineering and economic parameters to determine what could be done to make these systems more cost-effective.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: GROUND COUPLED SOLAR ASSISTED HEAT PUMP FIELD PERFORMANCE

PRIN. INVESTIGATOR: SAM V. SHELTON

ORGANIZATION: E-TECH, INCORPORATED

ADDRESS: 3570 AMERICAN DRIVE
ATLANTA, GA 30341

TELEPHONE NO.: (404) 458-6653

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 178,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-79SF10549

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JULY, 1979 **THROUGH** SEPTEMBER, 1980

PROJECT OBJECTIVES: To evaluate six ground coupled solar assisted heat pump systems in 4 geographical areas -- 2 in Atlanta, Georgia, 2 in Baltimore, Maryland and one each in Charleston, South Carolina and Tallahassee, Florida.

PROJECT DESCRIPTION AND STATUS: Both concepts under study utilize a water source heat pump, low temperature collector array, and a ground coil buried 4 feet beneath the surface. This ground coil consists of approximately 1000 feet of 1-1/2 inch polyethylene plastic pipe. In the first concept, the solar heat is put into the ground and the heat pump always uses the ground as its heat source. In the second concept, the solar heat is added only to a storage tank. The heat pump alternately uses either the storage tank or the ground as its heat source. All systems are comprehensively instrumented to gather operational performance data. This data will be collected and analyzed to determine each system's performance. All systems were in service by February 1980.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: THE PHOENIX HOUSE, CITY OF COLORADO SPRINGS SOLAR ASSISTED HEAT PUMPS

PRIN. INVESTIGATOR: DOUGLAS M. JARDINE

ORGANIZATION: KAMAN SCIENCES CORPORATION

ADDRESS: P.O. BOX 7463
COLORADO SPRINGS, CO 80933

TELEPHONE NO.: (303) 599-1555

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 466,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-79CS30207

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JUNE, 1979 **THROUGH** JUNE, 1981

PROJECT OBJECTIVES: To stimulate the development of a perferred ground coupled solar assisted heat pump system; to improve the system's performance and design data base; and, to conduct engineering field tests for the system on different types of building applications in different climatic regions of the United States--Colorado (residential), Ohio (industrial), and New Mexico (commercial).

PROJECT DESCRIPTION AND STATUS: This project is characterized as engineering field testing of preferred solar assisted heat pump (SAHP) systems in different climates. The performance of recent technological improvements in the form of new products which have been designed specifically to operate optimally within SAHP fluid heat sink and heat source requirements will be evaluated under controlled conditions. Technical and economic information on the performance of SAHP systems operating with ground coupled storage subsystems (GCSS) in various climates will be evaluated. Data will be gathered and the thermal performance of GCSS will be evaluated based on empirical data on soil temperatures, densities, thermal conductivity, and moisture contents. The output of this work will be the selection of the best marketable components and products for the SAHP, and knowledge of--and experience with--the operation of the preferred SAHP for space heating and cooling.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: INSTRUMENTATION AND MONITORING OF THE TWIN CROWN REALTY BUILDINGS IN DENVER, COLORADO

PRIN. INVESTIGATOR: DAVID K. HAYS

ORGANIZATION: SOLAR ENVIRONMENTAL ENGINEERING CO.

ADDRESS: 2524 EAST VINE DRIVE
FT. COLLINS, CO 80524

TELEPHONE NO.: (303) 221-5166

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 79,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-79CS30115

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JUNE, 1979 **THROUGH** DECEMBER, 1980

PROJECT OBJECTIVES: To monitor and evaluate the performance of the two solar augmented heat pump systems of the twin Crown Realty buildings in Denver, Colorado.

PROJECT DESCRIPTION AND STATUS: Two 3500 square foot commercial office buildings are environmentally conditioned by a system of seven solar augmented heat pumps and are identical in mechanical design with the exception of the solar collection loop. In one of the buildings, the collection loop is an air system while the other collection loop is a hydronic system. Thus, a direct comparison of an air and hydronic collection system can be made.

The two systems have been instrumented in order to provide all necessary data for complete system and subsystem performance analyses. The performance of the two systems will be determined by performing standard energy balances on the gathered data. Comparisons of the two systems will be made on the basis of collector efficiency, energy stored, energy utilized and other performance factors associated with the two systems.

The specific tasks are to:

- locate, select, purchase and install all sensors required for monitoring and analyzing the performance of the twin Crown Realty buildings;
- filter, reduce and analyze the gathered data to determine monthly load fractions; and,
- analyze systems performance by simulating real-time data reduction and analysis on the gathered data.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: LOW COST HEATING AND COOLING USING A DIRECT EXPANSION SOLAR COLLECTOR AND HEAT PUMP

PRIN. INVESTIGATOR: ELRIC W. SAASKI

ORGANIZATION: SIGMA RESEARCH, INCORPORATED

ADDRESS: 2950 GEORGE WASHINGTON WAY
RICHLAND, WA 99356

TELEPHONE NO.: (509) 735-0663

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 96,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-79SF10542

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JUNE, 1979 **THROUGH** AUGUST, 1980

PROJECT OBJECTIVES: To investigate the design and economics of a direct expansion solar collector and heat pump system.

PROJECT DESCRIPTION AND STATUS: In this new design, solar energy absorbed by exposed panels directly vaporizes a refrigerant fluid. The resulting low-temperature vapor is pumped to a high temperature and pressure and then condensed to release the heat absorbed in the vaporization process. The solar panels at most times operate at or below ambient temperature, resulting in a significant reduction in heat loss and eliminating the need for glass covers and insulation.

The new collector is particularly suited for heating in locales that experience large amounts of cloud cover and rainy weather because the panel continues to absorb energy by convection and radiation in the absence of solar input. In addition, condensation can provide significant thermal input to the collector under the proper meteorological conditions.

The use of a microprocessor to control the heat pump is expected to improve the average coefficient of performance (COP). The microprocessor will examine temperature throughout the system and control the compressor speed and perhaps the expansion valve to insure optimum performance.

The solar-assisted heat pump provides efficient utilization of available solar energy with a collector of minimal cost. In addition, the system provides significant heat output on cloudy days and during the night. These features coupled with the system's high COP make it very attractive for use in marginal solar heating areas.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: EVALUATION OF SOLAR COLLECTORS FOR HEAT PUMP APPLICATIONS

PRIN. INVESTIGATOR: C. GARY SKARTVEDT

ORGANIZATION: AMERICAN HELIOTHERMAL CORPORATION

ADDRESS: 2625 SOUTH SANTE FE
DENVER, CO 80223

TELEPHONE NO.: (303) 778-0650

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 98,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC04-78CS35351

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM SEPTEMBER, 1978 **THROUGH** JUNE, 1980

PROJECT OBJECTIVES: To evaluate the potential utility of low-cost, flat plate solar collectors as the heat source/sink for solar assisted heat pump systems for space heating and cooling; and, to conduct an experimental determination of effective night sky temperatures and convective heat transfer coefficients for surfaces with dimensions representative of flat plate solar collectors.

PROJECT DESCRIPTION AND STATUS: Hour-by-hour heating and cooling loads were calculated for typical single-family residences in eight U.S. cities. A detailed computer simulation model was developed for a solar-assisted liquid source heat pump system. The model includes provisions for ground-coupled thermal storage. Manufacturer's data and performance figures of merit were compiled for 20 commercially available collector configurations. System performance simulations were completed in four of the eight selected cities using a baseline unglazed plastic collector configuration and a typical glazed insulated collector.

Design calculations were completed for the night sky temperature/convection coefficient hardware. All materials and instrumentation equipment were purchased. Two identical test instruments have been fabricated and are ready for installation and checkout.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: INVESTIGATION OF HEAT PUMP IMPACT ON SOLAR COLLECTOR DESIGN AND COST

PRIN. INVESTIGATOR: JOHN W. ANDREWS
WILLIAM G. WILHELM

ORGANIZATION: BROOKHAVEN NATIONAL LABORATORY
SOLAR TECHNOLOGY GROUP

ADDRESS: BUILDING 701
UPTON, NY 11973

TELEPHONE NO.: (516) 282-4708

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 210,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: EY-76-C-02-0016

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JUNE 1978 **THROUGH** SEPTEMBER 1979

PROJECT OBJECTIVES: To assess the impact of advanced electric-powered heat pumps on the solar collector component of solar assisted heat pump systems; to investigate, by means of computer simulation, collector performance and cost specifications; and to identify low cost collector concepts consistent with cost/performance goals determined as above.

PROJECT DESCRIPTION AND STATUS: Advanced electric power heat pumps, designed to match the requirements of solar assisted heat pump systems, have been under development by the U.S. Department of Energy (DOE). These new heat pumps have far-reaching impacts on the performance requirements of other components of the system. This project assessed this impact on the solar collector component. Collector performance specifications set by system requirements have been determined and, using existing design procedures, collector concepts have been generated and evaluated. Cost reduction is the principal criterion for the evaluation. Test panels of selected designs were fabricated to provide point calibrations.

This project activity was divided into the following tasks:

Task I - System analysis to determine collector performance requirements.
Task II - Search for collector concepts meeting the requirements identified in Task I.
Task III - Cost vs yield analysis.
Task IV - Identification of cost factors and an analysis of the means for cost reduction.

In the follow-on project, thin-film collectors are being developed for direct heating and cooling as well as for heat pump applications.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ROCK BED STORAGE WITH HEAT PUMP

PRIN. INVESTIGATOR: HARRY E. REMMERS

ORGANIZATION: ZIA ASSOCIATES, INCORPORATED

ADDRESS: 5590 ARAPAHOE ROAD
P.O. BOX 1466
BOULDER, CO 80306

TELEPHONE NO.: (303) 449-9170

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 107,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC02-78CS34704

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM APRIL, 1978 **THROUGH** JUNE, 1979

PROJECT OBJECTIVES: To establish the technical feasibility, for most retrofit applications, of mating a heat pump to a rock-bed storage unit for optimal performance at the lowest cost.

PROJECT DESCRIPTION AND STATUS: This study analyzes the physical restraints involved in coupling a heat pump to a conventional rock-bed-storage type air system with flat-plate collectors. In order to incorporate accurate pricing and performance data into the study, only components currently available were used. The main result of the feasibility study is a control strategy which optimizes the performance of cost-effective heat pump/solar systems. These systems were modeled and subsequently analyzed using the TRNSYS computer program and a Life Cycle Cost Analysis program (LCCA). A detailed load model of a baseline house was formulated as a part of the TRNSYS analysis.

The analysis also resulted in the development of a technique to confine the range of heat pump/rock-bed storage systems to those systems which are economical for a specific location and set of economic conditions.

Several modifications and additions were made to the TRNSYS and LCCA computer programs during the course of the study.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF MARKETABLE SOLAR ASSISTED HEAT PUMPS

PRIN. INVESTIGATOR: ROGER HUNDT

ORGANIZATION: LENNOX INDUSTRIES, INCORPORATED

ADDRESS: 1600 METRO DRIVE, P.O. BOX 877
CARROLLTON, TX 75006

TELEPHONE NO.: (214) 245-2525

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,049,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-78CS31720

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM FEBRUARY, 1978 **THROUGH** MAY, 1981

PROJECT OBJECTIVES: To analyze, design, fabricate and test heat pumps which effectively utilize solar input in the 40°F to 110°F range to be used in optimized residential size solar assisted heat pump (SAHP) systems.

PROJECT DESCRIPTION AND STATUS: This project has been divided into three phases.

During Phase I (Conceptual Design and Commercialization and Marketing Plan), a study was conducted to identify a conceptual design and solar heat pump arrangement that would be marketable in quantity. This was accomplished by simulating various arrangements in various areas of the country. An in-line approach, adding solar energy directly to the evaporator of the heat pump, was identified for further study during Phase II (Detailed Design and Performance Prediction) because of its near-term potential for reaching the marketplace.

Phase II entails the detailed design of two system configurations of the in-line approach (with a reversing valve and without a reversing valve), accompanied by additional simulations and performance mappings. The most cost-effective in-line system will be chosen for fabrication, testing and prototype delivery to DOE during Phase III.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	30,000
WORKING FLUID/HEAT SOURCE/HEAT SINK:	R22/WATER/AIR
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	110/55
STEADY-STATE C. O. P. AT DESIGN TEMP.:	5

PROJECT SUMMARY

PROJECT TITLE: SOLAR ROCK BED AUGMENTED HEAT PUMP

PRIN. INVESTIGATOR: EDWARD F. SOWELL

ORGANIZATION: CALIFORNIA STATE UNIVERSITY

ADDRESS: FULLERTON, CA 92634

TELEPHONE NO.: (714) 870-3876

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 95,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AS02-78CS34697

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM FEBRUARY, 1978 **THROUGH** SEPTEMBER 1980

PROJECT OBJECTIVES: To define the performance advantages and disadvantages of a thermal storage/heat pump subsystem when used in the series-parallel configuration.

PROJECT DESCRIPTION AND STATUS: This project seeks to evaluate feasibility and cost-effectiveness of an arrangement of air-type solar collector rock-bed, and electrically-driven refrigeration machine for building heating and cooling. In this study, the condenser and evaporator are at opposite ends of the rock bed of an otherwise normal air-type solar heating system. The bed acts as a time delay for heating and cooling effects of the condenser and evaporator and thus stores heat, augmenting the heat pump at night and serving as cold-side storage during the cooling season. Optimum utilization of load management modes requires prediction of the next day's demand and solar availability. Efforts will be made to develop a complete strategy for mode selection and the implementation of this strategy as a TRNSYS subroutine.

Tasks completed to date are:

- developed TRNSYS-compatible computer simulation subroutines to model the rock bed and heat pump;
- performed a sensitivity analysis of the anticipated operating conditions to determine the relationship between the various parameters;
- performed life cycle cost analysis; and,
- prepared conceptual designs to predict performance and costs for the system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF A SOLAR ASSISTED HEAT PUMP FOR THE HEATING AND COOLING OF BUILDINGS

PRIN. INVESTIGATOR: AMIR ECKER

ORGANIZATION: NORTHRUP, INCORPORATED

ADDRESS: 302 NICHOLS DRIVE
HUTCHINS, TX 75141

TELEPHONE NO.: (214) 225-7351

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,072,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-78CS31718

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM FEBRUARY, 1978 **THROUGH** APRIL, 1980

PROJECT OBJECTIVES: To carry out the conceptual and detailed design, analysis, fabrication and testing of heat pumps which efficiently utilize solar input in the 40°F to 100°F range for heating and which also provide effective cooling for residential applications (1 to 5 tons); and to conduct studies of system configuration and commercialization potential are included.

PROJECT DESCRIPTION AND STATUS: The goal of this project was to develop the hardware for solar assisted heat pump (SAHP) systems which offer increased performance with minimum monetary trade-off. With the concomitant energy savings that accrue from the use of such systems, the impetus is thus provided for the marketing of SAHP systems, on a broad basis, as economically justifiable alternatives to conventional space conditioning equipment. In addition to the engineering development work associated with the analysis, design, fabrication and testing of advanced high performance heat pumps and related system hardware, a marketing analysis and plan was developed for producing and marketing these systems.

The scope of the design effort included the formulation of SAHP system designs for residential systems sized from one ton through four tons. The hardware development of optimized high efficiency vapor compression cycle heat pumps for use in conjunction with SAHP systems was the primary focus of the development work. Compressor capacity control and optimized heat exchangers were emphasized.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	30,000
WORKING FLUID/HEAT SOURCE/HEAT SINK:	R22/WATER/AIR
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	110/55
STEADY-STATE C. O. P. AT DESIGN TEMP.:	5

PROJECT SUMMARY

PROJECT TITLE: SOLAR HYBRID ENERGY PROJECT

PRIN. INVESTIGATOR: E. KERN

ORGANIZATION: M.I.T.
LINCOLN LABORATORY

ADDRESS: P.O. BOX 73
LEXINGTON, MA 02173

TELEPHONE NO.: (617) 862-5500 ext 7855

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,037,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: EG-77-S-02-4577

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 9/1/77 **THROUGH** 12/31/80

PROJECT OBJECTIVES: The objective of the Solar Photovoltaic/Thermal (Hybrid) Energy Project was to design, install, and experimentally evaluate residential solar heating and cooling systems which utilize a heat pump and either photovoltaic/thermal (PV/T) or exclusively photovoltaic (PV) collectors. PV/T collectors are solar collectors in which PV cells and flat-plate thermal collectors share a common aperture. PV power was provided by a utility-interactive PV power system. This power system is one in which a PV or PV/T array and an inverter operate in parallel with, and supply power to, a utility line. The inverter converts DC power obtained from the PV array to AC power which can be supplied either to the residence or the utility. Based on life-cycle cost considerations, recommendations were made concerning the most favorable heat pump and PV/T or PV collector system configurations for northern and southern climates. Based on these recommendations, residential and laboratory experiments were carried out to accomplish the following: (1) Identify factors affecting system operation which were not included in the design phase analyses, and to re-evaluate the results of these

PROJECT DESCRIPTION AND STATUS: During the design phase of the project a preferred residential heat pump and collector configuration was identified for both northern and southern climate locations. The preferred collectors [PV or PV/T] were identified for each location. Experimental data were used to quantify a temperature "defect" which may exist in previous simulations involving air-source heat pumps. Laboratory data were obtained which show that the steady-state operations of an air-source heat pump and a utility-interactive PV power system are compatible. Substantial data from a residential prototype system were obtained. These data establish the reliability and effectiveness of the combined heat pump and PV power system. It was demonstrated that the secondary heat pump functions of "boosting" and domestic hot water heating are difficult to perform effectively at low compressor speed.

PROJECT OBJECTIVES: (CONTINUED)

analyses, (2) Evaluate the effects of modifying commercially available heat pumps, (3) Evaluate the compatibility of a two-speed air-source heat pump and utility-interactive PV power system, and (4) Establish the reliability of a prototype system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SOLAR ASSISTED HEAT PUMP (SAHP)-2 ANALYTICAL SELECTION OF MARKETABLE SAHP SYSTEMS

PRIN. INVESTIGATOR: WILLIAM KAHAN

ORGANIZATION: SINGER COMPANY

ADDRESS: 286 ELDRIDGE ROAD
FAIRFIELD, NEW JERSEY 07006

TELEPHONE NO.: (201) 256-4000 x 569

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 336,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-77CS31467

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM SEPTEMBER, 1977 **THROUGH** APRIL, 1980

PROJECT OBJECTIVES: To identify the configurations of solar assisted heat pump (SAHP) systems and associated components that have the best market potential for the various climatic regions of the United States.

PROJECT DESCRIPTION AND STATUS: To achieve the program objective, an efficient analytical model was used to compare the thermal and economic performance of the following competing systems: 1) an all electric resistance heating system; 2) a stand-alone heat pump system; 3) a stand-alone solar energy system; 4) a series SAHP system; and 5) a parallel SAHP system. Thus, optimized systems were compared and ranked according to their marketability. This comparison was performed in a number of U.S. climates to assess the dependence of system rank on climate.

The life cycle costs of the competing systems were calculated for five U.S. locations. For each location calculations and comparisons were made for a large range of fuel costs at the time the system was installed. Furthermore, for each value of C_F (the cost of energy at the time of installation), the collector area and the storage volume (where appropriate) were sized to yield a minimum life cycle cost system. Thus, optimized vying systems were compared against each other.

The reported comparisons show that, where climate and fuel costs clearly justify an active solar energy system, the one with the lowest life cycle cost is the series SAHP system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: HEAT PUMPS IN DISTILLATION PROCESSES

PRIN. INVESTIGATOR: G. E. HARRIS

ORGANIZATION: RADIAN CORPORATION

ADDRESS: P. O. BOX 9948
AUSTIN, TEXAS 78766

TELEPHONE NO.: (512) 454-4797

SUBCONTRACTOR: NA
(if applicable)

EPRI PROJECT MANAGER:

John Brushwood
Project Manager, Unit Processes and Controls
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-2980

CONTRACT NO.: RP 1201-23

CONTRACT AGENCY: EPRI

CONTRACT PERIOD:

FROM 9/28/81 **THROUGH** 7/30/82

PROJECT OBJECTIVES: The primary objective of this study is to determine the range of applicability of electric driven heat pumps to distillation processes. Technical, economic, and market related constraints are to be considered in determining the potential applicability of heat pumps for both new and retrofit situations.

PROJECT DESCRIPTION AND STATUS: The approach to determine the range of applicability of heat pumps to distillation will include:

- a survey of heat pump system and component manufacturers,
- formulation of simplified external distillation models,
- formulation of open and closed cycle heat pump models,
- development of cost estimation routines for heat pumps,
- life cycle economic analysis of heat pump applications,
- FORTRAN program to perform the above analyses, and
- a survey and evaluation of candidate distillation processes.

This study is currently about 25 percent complete.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NA
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: HORIZONTAL GROUND COIL HEAT PUMP FIELD PERFORMANCE EVALUATION

PRIN. INVESTIGATOR: DR. ROBERT L. REID

ORGANIZATION: ENERGY, ENVIRONMENT, & RESOURCES CTR
MECHANICAL & AEROSPACE ENGINEERING DEPARTMENT
THE UNIVERSITY OF TENNESSEE

ADDRESS: 327 SOUTH STADIUM HALL
KNOXVILLE, TENNESSEE 37996

TELEPHONE NO.: (615) 974-5306

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 220,364

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	87%
UNIVERSITY OF TENNESSEE	13%

CONTRACT NO.: 7685 X92

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 9/15/81 **THROUGH** 9/14/84

PROJECT OBJECTIVES: To determine whether horizontal-coil ground-source heat pumps can be designed and operated successfully for U.S. climate conditions and loads using existing state-of-the-art design techniques.

PROJECT DESCRIPTION AND STATUS: A horizontal serpentine ground coil has been installed at the Tennessee Energy Conservation in Housing (TECH) test site in Knoxville which is operated jointly by the University of Tennessee, TVA, and ORNL. The coil was designed for the heating mode, using an existing design procedure, by another ORNL subcontractor (Battelle-Columbus Laboratories). The coil will provide a heat source/sink for an existing water-source heat pump previously operated by UT as a solar augmented system.

Data will be analyzed during and after each heating and cooling season to evaluate the performance of both the system and various components. This will include energy delivered, electrical consumption and demand, supplementary energy usage, heat flows from the ground coil, and earth temperatures. System performance factors will be determined on both a monthly and seasonal basis.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable.
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: IMPACT OF ELECTRICALLY DRIVEN HIGH TEMPERATURE INDUSTRIAL PROCESS HEAT PUMPS ON ELECTRICAL UTILITIES

PRIN. INVESTIGATOR: NEIL N. TURNER

ORGANIZATION: GENERAL ELECTRIC COMPANY

ADDRESS: BLDG. 23 ROOM 352
1 RIVER ROAD
SCHENECTADY, NY 12345

TELEPHONE NO.: (518) 385-0819

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:

John Brushwood
Project Manager, Unit Processes and Controls
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-2980

CONTRACT NO.: RP1967-2

CONTRACT AGENCY: EPRI

CONTRACT PERIOD:

FROM 8/81 **THROUGH** 5/82

PROJECT OBJECTIVES: To define the effects on utilities of large scale industrial heat pump utilization.

PROJECT DESCRIPTION AND STATUS: This project will: assess load impact on utilities, assess electrical noise effects due to load following, perform case studies and potential applications, define current state of research, define compressor performance maps and applications, and report on institutional and regulatory considerations.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

N.A.

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: WELL-WATER-SOURCE HEAT PUMP FIELD PERFORMANCE STUDY

PRIN. INVESTIGATOR: RICHARD S. DOUGALL

ORGANIZATION: UNIVERSITY OF PITTSBURGH

ADDRESS: MECHANICAL ENGINEERING DEPARTMENT
648 BENEDUM HALL
PITTSBURGH, PA 15261

TELEPHONE NO.: (412) 624-5335

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 75,932.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: ORNL/sub-7985

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM OCTOBER, 1980 **THROUGH** OCTOBER, 1982

PROJECT OBJECTIVES: The objective of this study is to obtain and analyze data pertaining to the field performance characteristics of two well-water-source heat pumps (WWSHP) which are installed in two residences located in rural south-central Pennsylvania. These were existing single-family residences which were retrofitted with WWSHP. The heat pump installations are being instrumented with an automated data gathering system which will allow the performance of the systems to be evaluated. The first major aim of this project is to evaluate the data obtained so that seasonal performance factors and energy consumption characteristics of the WWSHP may be evaluated. The second major aim of this project is to develop a mathematical model that simulates the actual performance satisfactorily and then to use this model to compare WWSHP with other heating and cooling systems.

PROJECT DESCRIPTION AND STATUS: The present project is the data analysis and modeling phase related to a comparison project which involves data gathering. This companion project is being performed by Allegheny Electric Cooperative, Inc., Harrisburg, PA and funded EPRI.

The well-water-source heat pump (WWSHP) has an important advantage over air-to-air heat pumps in that the heat source (i.e., well-water or other ground water) remain at a relatively uniform temperature throughout the year. This means the COP remains reasonably high, even when outdoor air temperature becomes very low. This means that WWSHP have the potential of being an economical system for heating rural residences in northern climates when these residences have an easily available supply of ground water.

This program is in its early stages. The heat pumps being monitored have been installed in the residences. The data acquisition systems with their sensors have been obtained. The debugging and installation of this equipment in the houses is in progress. The data gathering and modeling phases of this project have not yet started.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: N/A
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SOLAR HEAT PUMP SIMULATOR

PRIN. INVESTIGATOR: MARK A. CATAN

ORGANIZATION: BROOKHAVEN NATIONAL LABORATORY

ADDRESS: BUILDING 701
UPTON, NEW YORK 11973

TELEPHONE NO.: (516) 282-2504

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 175,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC02-76CH00016

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM OCTOBER, 1980 **THROUGH** SEPTEMBER, 1981

PROJECT OBJECTIVES: The objectives of this project are to demonstrate the feasibility of constructing heat pumps capable of achieving high COP's at high evaporating temperatures, to explore the practical means to realize and enhance this performance potential; to test prototype solar heat pumps produced by contractors under the SAHP program; to identify solar heat pump systems which best exploit the realizable potential.

PROJECT DESCRIPTION AND STATUS: A heat pump hardware simulator capable of testing water-to-water heat pumps operating in steady state and unsteady state modes has been constructed. An water-to-water heat pump was built using "off the shelf" components and tested at high and low source temperatures. Results of these tests demonstrated the feasibility of achieving continuously rising COP and were used to establish goals for the SAHP program.

The simulator was upgraded to accommodate water-to-water heat pumps and used to test, under steady state and unsteady state conditions, the first of two prototype SAHP's developed under DOE contract. Results of these tests demonstrated that the nominal goal of COP of 6 at water source temperature of 90 F was achieved.

Presently the simulator is being modified to accommodate the second prototype SAHP. A heat pump component test facility, to be used for component optimization studies, is under construction. A cooperative experimental effort between several heat exchanger manufacturers and BNL to identify optimal refrigerant heat exchangers for marketable SAHP's is under way.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 to 48,000 Btu/hr

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-12, R-22/water/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 100 to 400 F / 30 to 100 F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 3.0 to 9.0

PROJECT SUMMARY

PROJECT TITLE: GROUND ENERGY COUPLING

PRIN. INVESTIGATOR: Philip D. Metz

ORGANIZATION: BROOKHAVEN NATIONAL LABORATORY

ADDRESS: Building 701
Upton, NY 11973

TELEPHONE NO.: (516) 282-3596

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 190,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC02-76CH00016

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM OCTOBER, 1980 **THROUGH** SEPTEMBER, 1981

PROJECT OBJECTIVES: The goal of this research program is to determine the feasibility of ground coupling for various heat pump systems, and if feasibility is confirmed, to create comprehensive and reliable design guidelines for optimal ground coupled heat pump systems.

PROJECT DESCRIPTION AND STATUS: The possibility of using the ground as an energy source or storage element has been studied often because it represents an available and inexpensive resource applicable to many systems. This project will study its application and potential impact on heat pump systems. Analysis and field results indicate that the ground is a satisfactory moderate temperature heat source/sink. As a result, ground coupled heat pump systems have great potential for economy and energy efficiency. Resistive heating is never used which reduces energy consumption and utility generating capacity requirements while increasing load factors. At the same time, the defrost cycle - and its related stress to the heat pump - is eliminated. This project will start from a literature search base and will assemble ground energy coupling computational methods. From these methods energy transfer and recovery characteristics will be estimated and checked by field experiment. These characteristics will be fed into heat pump system analysis routines already existing at Brookhaven National Laboratory (BNL). System impact will be evaluated. The control field experiments will consist of tanks and pipes installed in the ground using configurations to be developed early in the project. These field tests will be conducted as a scientific experiment with some of the installed equipment operated as a control.

A digital computer program called GROCS has been written to model 3-dimensional underground heat flow in order to accurately simulate the behavior of ground coupling devices. Both soil thermal property and 12 ground coupling device experiments are underway at BNL, including 4 buried tanks, 7 earth coils in various configurations and lengths, and 1 group of 6 sealed vertical wells. One earth coil has been used to heat a house on the BNL site with no use of resistance heating. Computer model predictions have been compared to experimental design procedures.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

MONITORING OF RESIDENTIAL WATER-SOURCE HEAT PUMPS

PRIN. INVESTIGATOR: Gilbert M. Freedman

ORGANIZATION: Allegheny Electric Cooperative

ADDRESS: 212 Locust Street
P.O. Box 1266
Harrisburg, PA 17108

TELEPHONE NO.: (717) 233-5704

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP1201-14

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 9/22/80 **THROUGH** 11/20/82

PROJECT OBJECTIVES:

The primary objective of this project is to measure the technical performance of residential water-source heat pumps in retrofit applications for rural residences. The performance and cost data obtained will be compared with other types of heating (air-to-air heat pumps; oil, gas, and electric furnaces; and active solar) systems.

PROJECT DESCRIPTION AND STATUS:

This project examines groundwater heat pumps including:

- Field monitoring of two water-to-air heat pumps,
- Performance comparison to alternative systems,
- Comparison of costs, and
- Evaluation of utility impacts.

The two heat pumps were installed as retrofits to oil- and coal-fired furnaces in rural Pennsylvania locations. One site uses water reinjection into a second well and the other uses surface disposal. The University of Pennsylvania (UoP) is analyzing the data and modelling both the heat pumps and alternative systems under a separate contract with Oak Ridge National Laboratory (ORNL).

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

AN INVESTIGATION OF GROUND SOURCE HEAT PUMPS USING DIRECT EXPANSION

PRIN. INVESTIGATOR: MARK D. KALMAN

ORGANIZATION: E-TECH, INC.

ADDRESS: 3570 AMERICAN DRIVE
ATLANTA, GA 30341

TELEPHONE NO.: (404) 458-6643

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 138,246.00

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: SUBCONTRACT 86X-61612C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM SEPTEMBER, 1980 **THROUGH** AUGUST, 1982

PROJECT OBJECTIVES: To perform an experimental investigation and feasibility assessment of direct expansion of refrigerant in an earth heat exchanger as a means for utilizing the ground as a heat source/sink for heat pumps. Particularly to demonstrate that the proposed direct expansion concept is technically feasible as a ground source evaporator and a ground sink condenser. The economic viability of the system including the practicality of its installation is being considered. Sufficient thermal performance and design data is being collected to permit evaluation of the energy conservation potential of this technology.

PROJECT DESCRIPTION AND STATUS: The project is divided into two tasks. First a small scale, well instrumented, variable capacity, ground coupled heat pump system was developed and built. Pressures and temperatures are measurable at various locations around the heat pump circuit. Refrigerant flow rate is measurable to determine system heating and cooling capacity. Three types of earth heat exchangers have been tested under heating conditions (ground cooling) with this experimental apparatus. The system is reversible and the same earth heat exchangers will be tested under cooling conditions (ground heating). Various refrigerant flow control and compressor protection devices are being tested for applicability to the direct expansion system.

The best earth heat exchanger configuration as determined in Task 1 will be used as a model for development of a full scale system in Task 2. One or more 2 1/2 ton prototype systems will be designed and constructed. The refrigerant flow control and compressor protection devices that are determined to be most applicable in Task 1 will be used in the full scale systems developed in Task 2.

Presently an open type compressor is being used on the subscale system of Task 1. However, there was a problem with minor amounts of liquid floodback causing bearing damage, even with the use of a suction accumulator. A hermetic compressor is being installed in its place as these units are more compatible with such operation. This will be a fixed capacity unit, but our previous experimentation has indicated the required compressor model.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 30,000 BTU/HR (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-22/ground/air (heating)

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 100°F/-10°F - 10°F (heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 2.5 - 3 (heating)

PROJECT SUMMARY

PROJECT TITLE: CONDUCT A STATE-OF-THE-ART SURVEY OF EXISTING KNOWLEDGE FOR THE DESIGN OF GROUND-SOURCE HEAT PUMPS

PRIN. INVESTIGATOR: DAVID A. BALL

ORGANIZATION: BATTELLE
COLUMBUS LABORATORIES

ADDRESS: 505 KING AVENUE
COLUMBUS, OHIO 43201

TELEPHONE NO.: (614) 424-4901

SUBCONTRACTOR: (if applicable) BATTELLE-INSTITUT e.V.
AM ROMERHOF 35
6000 FRANKFURT/MAIN 90
WEST GERMANY

DR. DAVID HODGETT
Phone: 49-611-79080

TOTAL FUNDING: $ 100,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: SUBCONTRACT NO. 7800, LETTER RELEASE NO. X06

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM SEPTEMBER, 1980 **THROUGH** MAY, 1981

PROJECT OBJECTIVES: The objectives of this program are to gather design and performance information on historical and current ground-coil heat-pump systems, to assess the adequacy of available design methods, and to define near-future R&D needs to promote the use of this technology.

PROJECT DESCRIPTION AND STATUS: The project was generally separated into two parts: (1) a review of North American technology being conducted by Battelle-Columbus, and (2) a review of European technology being conducted by Battelle-Frankfurt. A draft report describing European technology was completed in March of 1981, and the overall draft report is expected to be completed around the end of May.

This project has uncovered a substantial volume of historic and current research on ground-coil heat-pump technology. Approximately 27 individual ground-coil heat-pump design and simulation methodologies have been studied. In addition, numerous visits and phone contacts have been made throughout Europe and North America to obtain information on the status of various ground-coil activities. A news release describing this study was issued in December, 1980, and has resulted in a significant number of individuals and local installers responding with information on their experience and activities in ground-coil heat-pump systems.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: OPEN-CYCLE HEAT PUMP FOR INDUSTRIAL WASTE HEAT UTILIZATION

PRIN. INVESTIGATOR: C. R. SNYDER

ORGANIZATION: GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH AND DEVELOPMENT

ADDRESS: P.O. Box 43
SCHENECTADY, NY 12301

TELEPHONE NO.: (518) 385-0162

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 112,000 (authorized)

SOURCE(S)	LEVEL (%)
OAK RIDGE NATIONAL LABORATORY	81.39
NEW YORK STATE ERDA	18.66

CONTRACT NO.: 86X-24717C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM MAY 12, 1980 **THROUGH** OCTOBER 12, 1980

PROJECT OBJECTIVES: The objective of the Phase I was to study the feasibility of the open-cycle industrial process heat pump at several sites for the purpose of demonstrating the concept.

PROJECT DESCRIPTION AND STATUS: The feasibility study was completed with evaluation of three sites and four process configurations. The site visits provided process information on flow rates, process temperatures, pressures, dynamics behavior, energy balances, control functions, and plant operating philosophy. Additional information on the plant utilities and possible equipment location was also obtained. Comparative evaluations were made considering energy savings, cost savings, value of operating experience and potential for wide application. Energy cost and application potential information was gathered for New York State. Component costing was completed on two process configurations showing merit. The Phase I report indicated that two applications were possible for either a full-scale or a smaller demonstration-size prototype. Presently, Oak Ridge has asked for our comments on a change in workscope on the remaining phase of the contract.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 25,000,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Steam/water/steam

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 170° inlet water flow/50 PSIA saturated outlet

STEADY-STATE C. O. P. AT DESIGN TEMP.: 4.6

PROJECT SUMMARY

PROJECT TITLE: SOLAR ENERGY EARTH STORAGE SYSTEM (SEESS) MINI-PROTOTYPE TESTING PROGRAM

PRIN. INVESTIGATOR: S. W. YUAN

ORGANIZATION: RISE, INCORPORATED

ADDRESS: 6701 MONTOUR DRIVE
FALLS CHURCH, VA 22043

TELEPHONE NO.: (703) 534-6177

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 10,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AP03-80SF11121

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM FEBRUARY, 1980 **THROUGH** AUGUST, 1980

PROJECT OBJECTIVES: To complete the investigation of a 1/10 scale experiment of a solar energy earth storage system.

PROJECT DESCRIPTION AND STATUS: The system under investigation consists of a volume of earth isolated from its surroundings by an impermeable membrane. Moisture migration away from the membrane is predicted which will generate a zone of low moisture content, hence low thermal conductivity, impeding heat loss from the storage volume.

The performance of the 1/10 scale model of an earth-coupled heat transfer system was evaluated. Hourly temperature data were recorded and monthly and annual heat losses from storage were determined.

Theoretical calculations of the expected changes in earth temperature during the winter were made based on heat loss and heat use.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: CRAWL SPACE-ASSISTED HEAT PUMPS

PRIN. INVESTIGATOR: RALPH N. McGILL

ORGANIZATION: OAK RIDGE NATIONAL LABORATORY

ADDRESS: P.O. BOX Y
OAK RIDGE, TN 37830

TELEPHONE NO.: (615) 574-4077

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ Not available

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.:

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM October 1979 **THROUGH** Continuing

PROJECT OBJECTIVES: The objective of this project is to determine the extent to which the performance of an air-to-air heat pump can be improved and made more efficient by making use of the thermal energy that is stored naturally in the earth of the crawl space of a house to preheat (or precool) the source air of the heat pump. Both experimental and analytical studies are to be used to achieve the project objective.

PROJECT DESCRIPTION AND STATUS: This project is being pursued as part of the in-house Technology Development portion of the Thermal Energy Storage Program which is managed by the Oak Ridge National Laboratory for the U.S. Department of Energy.

Thus far, by means of field tests in real houses, we have found that the source air for the heat pump can be preheated (or precooled) by drawing the outdoor air through the crawl space before it is used by the heat pump. The outdoor air is warmed (or cooled) by flowing over the crawl space earth. Most of the data is from winter months, when we would expect the most benefit for heat pump performance. Generally, greater preheating occurs at lower outdoor air temperatures; and, the effect tapers off to virtually no gain at about 10°C. The preheating effect has been shown to be sustained for an entire winter season. Another experiment proved that the preheating does come, in great part, from the earth and not simply from the house above. Analysis has also led us to believe that the heat transfer mechanism is by simple conduction within the upper 0.3 m of the crawl space earth.

Although the preheating effect of the crawl space has been proven, we do not yet know whether this effect will be beneficial to heat pump performance. Therefore, the current efforts of the project are twofold. First, with three identical houses, leased by us and unoccupied, we will carry out comprehensive tests of the concept to determine the extent to which the efficiency of a heat pump might be improved by this method. Secondly, computer modeling efforts are underway to describe the crawl space earth and air behavior. Mating of this model, after it is validated, with existing heat pump models should allow us to be able to predict the extent of benefits that might be attained in different climates.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: OPEN-CYCLE ELECTRIC-DRIVEN INDUSTRIAL HEAT PUMP

PRIN. INVESTIGATOR: H. M. LEIBOWITZ AND D. W. CHAUDOIR

ORGANIZATION: MECHANICAL TECHNOLOGY INCORPORATED

ADDRESS: 968 ALBANY-SHAKER ROAD
LATHAM, NEW YORK 12110

TELEPHONE NO.: (518) 785-2211

SUBCONTRACTOR: (if applicable) FORD, BACON AND DAVIS UTAH, INC.
375 CHIPETA WAY
SALT LAKE CITY, UTAH 84108

TOTAL FUNDING: $407,924

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 86X-24713C

CONTRACT AGENCY: UNION CARBIDE CORPORATION-NUCLEAR DIVISION
OAK RIDGE, TENN.

CONTRACT PERIOD:

FROM September 1979 **THROUGH** September 1981

PROJECT OBJECTIVES: The objective of the design phase of the project is to develop a detailed design of a demonstration-size open-type Rankine-cycle heat pump, which would demonstrate the system's technical concept.

PROJECT DESCRIPTION AND STATUS: The present phase of this project is part of an R&D effort to evaluate the potential uses of low-temperature heat sources (130-200°F). Mechanical Technology Incorporated (MTI) has developed an open-Rankine-cycle heat pump that will utilize this low-temperature energy. The heat pump is characterized by the lack of both an evaporator on the heat source side and a condenser on the process side, thus the Open-Open™ heat pump concept.

The Open-Open™ heat pump utilizes the heat source, clean waste water streams, as the system's working fluid and also as the eventual process fluid. The system accomplishes the transition by directly flashing the waste water stream in a critically sized flash tank. The water vapor is then compressed to a useable temperature and pressure by a series of single-stage centrifugal compressors. The compression train features a desuperheat station after each stage. The desuperheat station reduces the temperature of the steam to a reasonable level to permit the use of standard materials in the compressor, thereby yielding the extra benefit of reducing the required compression power. After the compression/desuperheat process, the fluid is directed to the process use.

The design of the heat pump system was accomplished by a joint effort of MTI and Ford, Bacon and Davis Utah, Inc. (FB&DU), under subcontract to MTI, and consisted of developing system diagrams and specific component purchase specifications. Four heat pump subsystems make up the heart of the design. These subsystems include the flashing process, compression/desuperheat process, motor control center, and microprocessor-based control systems.

The detailed design was completed in February 1981. An updated cost estimate has been submitted, and MTI is presently awaiting the decision as to whether the demonstration heat pump will be built.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: (PILOT PLANT SPECIFICATIONS)
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 4.76×10^6 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Water Vapor/150°F Water/Process

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 239°/150°

STEADY-STATE C. O. P. AT DESIGN TEMP.: 4.36

PROJECT SUMMARY

PROJECT TITLE: GROUND-WATER HEAT PUMPS: AN EXAMINATION OF HYDROGEOLOGIC, ENVIRONMENTAL, LEGAL, AND ECONOMIC FACTORS AFFECTING THEIR USE

PRIN. INVESTIGATOR: D. J. BACON and T. E. GASS

ORGANIZATION: NATIONAL WATER WELL ASSOCIATION

ADDRESS: 500 WEST WILSON BRIDGE ROAD WORTHINGTON, OHIO 43085

TELEPHONE NO.: (614) 846-9355

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 124,293

SOURCE(S)	LEVEL (%)
DOE	100%

CONTRACT NO.: EM-78-C-01-4278

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 9/28/78 **THROUGH** 3/28/80

PROJECT OBJECTIVES:

The purpose of this project was to assess the feasibility of expanded use of ground water as a heat source for heat pumps.

PROJECT DESCRIPTION AND STATUS:

This project was comprised of three principal tasks, which are described in the following paragraphs:

Task 1. Collection of Hydrogeologic and Climatologic Data. This task involved assessing the availability and characteristics of ground water supplies throughout the United States for use with ground water-source heat pumps. This assessment was made on a state-by-state basis and included evaluation maps for each state. Water quality was considered, as it affects the performance and life expectancy of the water-to-refrigerant heat exchanger and, in extreme cases, the technical viability of the ground-water heat pump option.

Task 2. Economic and Energy Analysis of Ground-Water Source Heat Pumps. Using information and data collected in Task 1, together with manufacturers' performance data on water-source heat pump performance, a comparative analysis of the energy consumption and owning and operating cost of ground-water heat pumps was undertaken. The analysis was based on an hour-by-hour computer simulation of the performance of the ground-water heat pump and more conventional heating/cooling systems in a typical single-family residence in nine cities representative of the various geographic and climatic regions.

Task 3. Environmental and Legal Consequences of Using Ground Water As an Energy Source. This task involved evaluating the environmental problems that can potentially result from expanded use of ground-water source heat pumps and conducting a survey of Federal, state, and local regulations that might affect the potential use of ground-water heat pumps.

It was concluded that ground-water-source heat pumps can effect significant energy savings, compared to air-source heat pumps. The economics are very favorable so long as the cost of the well is not chargeable to the heat pump system. If one or more wells must be charged to the system, the economics may or may not be favorable.

This project has been completed and the final report is available.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

Not applicable.

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DESIGN AND FIELD TESTING OF SOLAR-ASSISTED EARTH COILS

PRIN. INVESTIGATOR: JAMES E. BOSE

ORGANIZATION: OKLAHOMA STATE UNIVERSITY

ADDRESS: 101 INDUSTRIAL BUILDING
STILLWATER, OK 74074

TELEPHONE NO.: (405) 624-5638

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 260,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AS03-79CS30210

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM AUGUST, 1978 **THROUGH** JANUARY, 1981

PROJECT OBJECTIVES: To design and operate a set of instrumented field experiments to obtain engineering information and data needed for optimum design of ground energy coupling devices for use in solar assisted heat pump systems.

PROJECT DESCRIPTION AND STATUS: A field demonstration laboratory using unprepared earth as a heat sink/source device has been under development at Oklahoma State University since June, 1977. The demonstration laboratory consists of a 1,000-foot horizontal earth coil and two vertical heat exchangers. The horizontal heat exchanger is a 4-inch polyvinylchloride (PVC) pipe buried in a serpentine pattern at a depth of 4 feet. Undisturbed temperatures of this depth are cyclic and depend on latitude, moisture content, and soil type.

Two types of earth coils have been designed, constructed, and are operational on the Oklahoma State University campus. The 1,000-foot, 4-inch PVC coil has been the heat source/sink for two commercial heat pump systems.

Integral to the earth coil is a 1,000-gallon uninsulated storage tank in which solar energy from 200 ft^2 of solar collectors can be added directly to the heat pump or circulated through the 1,000-foot earth coil system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: COMPARISON OF CENTRALIZED AND DISTRIBUTED HP-ICES THAT USES LOW TEMPERATURE INDUSTRIAL WASTE HEAT

PRIN. INVESTIGATOR: LINCOLN B. KATTER

ORGANIZATION: ROCKET RESEARCH COMPANY

ADDRESS: 11441 WILLOWS ROAD
REDMOND, WA 98052

TELEPHONE NO.: (206) 885-5000

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 71,941

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4546

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 6/20/78 **THROUGH** 11/30/79

PROJECT OBJECTIVES: To compare centralized and distributed heat pump centered integrated community energy systems that use low temperature industrial waste heat. Service options evaluated were space heating, cooling, water heating, and combinations thereof. Geographic location, overall system size, and heat source characteristics were the major factors addressed. The HP-ICES considered incorporated two-pipe systems using water as the thermal transport medium.

PROJECT DESCRIPTION AND STATUS: Case studies for application were made for Everett, WA, Seattle, WA, and San Antonio, TX. In all cases, on-site use of oil is eliminated by HP-ICES. However, winter electricity use increased by 50 percent in Everett, which would not make this HP-ICES attractive here although life-cycle costs were favorable here. For Seattle, winter electricity demand increased somewhat, summer electricity decreased, but without real escalation in oil prices beyond inflation, HP-ICES economics are very unattractive. For San Antonio, both summer and winter electricity demands increased by 50 percent: payback is not achieved within 15 years, and life-cycle costs of HP-ICES are unfavorable.

It was concluded that for the HP-ICES systems considered and sites applied, payback is never attractive enough to encourage investment. Life-cycle costs are marginally attractive and indicate that the most attractive sites have a high density of end-users that are located close to the waste heat source. However, these sites tend to be in established neighborhoods where large-scale construction necessary for pipeline installation and customer hook-ups would probably not be encouraged unless outstanding economics could be demonstrated.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SYSTEM DEVELOPMENT STUDY OF HP-ICES USING A DISTRIBUTED SYSTEM AND GROUND WATER AS SOURCE AND SINK

PRIN. INVESTIGATOR: WALTER J. SCHAETZLE
C. EVERETT BRETT
MARVIN S. SEPPANEN

ORGANIZATION: BUREAU OF ENGINEERING RESEARCH AND NATURAL RESOURCES CENTER

ADDRESS: UNIVERSITY OF ALABAMA
UNIVERSITY, AL. 35486

TELEPHONE NO.: (205) 348-6010

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $64,378

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4550

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 6/20/78 **THROUGH** 11/30/79

PROJECT OBJECTIVES: To analyze the feasibility of applying a heat-pump centered integrated community energy system (HP-ICES) using water from aquifers as the source, sink, and distribution medium to provide space heating and cooling. The aquifer (accessed by at least two wells) is also used for annual storage of thermal energy without consumptive use and requiring only low-temperature lift. This particular HP-ICES system was analyzed as demonstration projects for a portion of downtown Louisville, KY (major buildings), and a section of Fort Rucket, AL. (dispersed subdivision of homes).

PROJECT DESCRIPTION AND STATUS: Economically, this particular HP-ICES system shows improvement on both energy usage and capital costs. The system saves over 60 percent of the energy required for resistance heating, saves over 30 percent of the energy required for most air-source heat pumps, and saves over 60 percent of the energy required for gas, coal, or oil heating when compared to energy input required at the power plant for heat pump consumption. Capital costs for this particular HP-ICES are lower than a standard air-source heat pump system or gas, oil, or coal heating system-plus air conditioner. In general, for a small residence or small commercial system, an air-source heat pump capital cost is approximately 100 percent more than an equivalent water-source heat pump with the same ARI listed capacity; however, this can be offset by the cost of wells and the water distribution system.

In the demonstration projects, the Louisville HP-ICES showed a payback of 3 years while Fort Rucker showed 30 years. The primary difference is that at the latter new heat pumps are charged to the system while at the former either new construction requiring heating and cooling systems or existing chillers are utilized.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ASSESSMENT OF HP-ICES CONCEPT RECOVERING HEAT FROM WASTE WATER WITH CASCADED HEAT PUMPS

PRIN. INVESTIGATOR: D. W. WADE

ORGANIZATION: GEORGIA INSTITUTE OF TECHNOLOGY

ADDRESS: GEORGIA TECH. RESEARCH INST. ATLANTA, GA. 30332

TELEPHONE NO.: (404) 894-2000

SUBCONTRACTOR: (if applicable) McCURRY AND ASSOCIATES

TOTAL FUNDING: $ 58,167

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4551

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 6/20/78 **THROUGH** 12/31/79

PROJECT OBJECTIVES: To develop the concept of a heat pump centered integrated community energy system (HP-ICES) that reclaims low-grade thermal energy from a community's waste water effluent, evaluate its potential performance and economics, and examine its potential application. Cascaded electrically-driven heat pumps are used with the extracted heat delivered by a moderate-temperature water piping system. Heat is removed from the piped water by each subscriber for space heating.

PROJECT DESCRIPTION AND STATUS: A thermodynamic performance analysis projects an overall coefficient of performance from 2.181 to 2.264 for waste water temperatures from 50°F to 80°F for this particular HP-ICES. Site-specific designs for this HP-ICES are presented for application in Conyers, and Cornelia, GA. Economic analysis on the basis of a life-cycle cost comparison shows that application in Conyers would be more costly than conventional systems due to the current low energy costs for natural gas heating. On the other hand, similar analysis for application in Cornelia shows that this particular HP-ICES as designed specifically for this site to be cost-competitive in the immediate market with conventional residential and light commercial HVAC systems. The primary environmental concern of this HP-ICES is its impact on sewage treatment: high rates of heat recovery from wastewater effluent may reduce biodigestion rates and high rates of heat rejection to the effluent may be so severe as to kill the bacteria essential for biodigestion.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS) Not applicable

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

DEVELOPMENT AND DEMONSTRATION OF AN ELECTRIC HEAT PUMP FOR WASTE HEAT RECOVERY IN INDUSTRY

PRIN. INVESTIGATOR: W. C. Moreland

ORGANIZATION: Westinghouse Electric Corporation

ADDRESS: Research and Development Center
1310 Beulah Road
Pittsburgh, PA 15235

TELEPHONE NO.: (412) 256-5103

SUBCONTRACTOR: (if applicable)

To be identified before proposing Phase 2 contract for industrial demonstration.

TOTAL FUNDING: $ 2,312,619 (Phase 1 only)

SOURCE(S)	LEVEL (%)
Department of Energy	88.5
Westinghouse Electric Corp.	11.5

CONTRACT NO.: DE-AC01-77CS40327

CONTRACT AGENCY: DOE Headquarters Procurement Operations Office

CONTRACT PERIOD:

FROM July, 1977 **THROUGH** July, 1982

PROJECT OBJECTIVES:

Demonstrate technical feasibility and economic viability of using electrically driven heat pumps to reclaim low temperature waste heat from industrial processes. The specific technical and economic goals are:

Delivery temperatures in the range of 250 to 350°F
Source temperatures in the range of 180 to 250°F
Paybacks of four years or less

PROJECT DESCRIPTION AND STATUS:

The Westinghouse R&D Center, under contract to the Department of Energy, is developing an electrically driven high temperature heat pump which will extend the technology more than 100°F above that of available commercial units. This is a two phase project in which the first phase covers the development, design, fabrication, and laboratory testing of a prototypical unit. A second phase would cover the actual installation and demonstration of this heat pump at an industrial partner's plant.

Under this contract the critical aspects of the basic technology required for extending the high temperature capability of heat pumps have previously been identified and investigated. On the basis of this work, methanol was selected as the preferable working fluid for the new heat pump and extensive testing performed to determine the thermal stability of methanol and its compatibility with various alloys and elastomeric materials.

This technical effort has been supplemented by a number of application studies which indicate that such heat pumps can be cost effective in reducing fossil fuel consumption in particular applications. These studies have concentrated on the pulp and paper industry. This industry is a major consumer of fossil energy and has both process energy requirements and waste heat sources within the thermal capability of the high temperature heat pump.

The design of the heat pump and test loop have been completed and quotes obtained on all equipment items. Estimates have been obtained on installation costs for the planned test site at the Westinghouse R&D Center. The project is now awaiting the approval of DOE for procurement of the long lead components.

After fabrication of the system and test loop, a series of extended tests will be undertaken at our laboratory site to verify the technology. Since a novel and previously unproven refrigerant (methanol) is being used in the heat pump, such a test program is mandatory to demonstrate both reliability and proven performance to potential industrial customers.

Based on the heat pump system component cost and an estimate of installation cost at a particular industrial site, a calculation using the fossil fuel and electric prices at this site yields a simple payback of less then two years.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 30×10^6 Btu/h

WORKING FLUID/HEAT SOURCE/HEAT SINK: Methanol/atmospheric pressure steam/50 psig process steam w/20° superheat

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 313°F/197°F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 4.5

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF CONCEPTS FOR LOW COST ENERGY STORAGE ASSEMBLIES FOR ANNUAL CYCLE ENERGY SYSTEM APPLICATIONS

PRIN. INVESTIGATOR: D. L. COOPER

ORGANIZATION: BATTELLE COLUMBUS LABORATORIES

ADDRESS: 505 KING AVENUE
COLUMBUS, OH 43201

TELEPHONE NO.: (614) 424-7411

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 59,147

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 7800X07

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 9/12/80 **THROUGH** 5/31/81

PROJECT OBJECTIVES: To devise and evaluate diverse storage concepts and to develop detailed designs for those that promise minimum cost while still meeting the functional requirements of ACES.

PROJECT DESCRIPTION AND STATUS: The project is completed. Battelle evaluated a large number of ice storage tank/heat exchanger coil configurations and designs, and detailed the design of three of the most promising of these. Because of the requirements for high insulation and mechanical integrity for long periods (20 years or more), none of the designs led to substantial reductions in cost. The work is documented in the report: "Development of Concepts for Low-Cost Energy Storage Assemblies for Annual Cycle Energy System Applications," ORNL/Sub-7800/1, available from NTIS.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ASSESSMENT OF HP-ICES BASED ON A CENTRALIZED SYSTEM AND ANNUAL CYCLE ENERGY STORAGE

PRIN. INVESTIGATOR: FRED S. DUBIN

ORGANIZATION: DUBIN BLOOME ASSOCIATES

ADDRESS: 42 WEST 39TH STREET
NEW YORK CITY, NY 10018

TELEPHONE NO.: (212) 840-6780

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 66,850

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4549

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 6/20/78 **THROUGH** 11/30/79

PROJECT OBJECTIVES: To assess the feasibility of a heat pump centered integrated community energy system (HP-ICES) based on a community scale, annual-cycle energy storage approach using both latent and sensible thermal energy storage with water as the medium. This centralized system uses an ice-making heat pump driven by an electric motor or an engine. Space heating and cooling as well as service-water heating are provided. Detailed case studies of applying this HP-ICES concept were made on the market square project in Washington, D.C., and Park Plaza in Boston, MA.

PROJECT DESCRIPTION AND STATUS: The ice-generating HP-ICES uses the heat of fusion of water as a heat source, converting water into ice. The annual overall coefficient of performance is expected to reach a value of 4.85 and related to source energy, a value of 4.85 x 0.31 = 1.5. This is greater than 0.713, the value for which the HP-ICES would perform equally well with a conventional system having the same cooling and heating output.

In the Washington, D.C. case study, it was found that the annual source energy input is about 60 percent and the life-cycle annual average cost is 40 percent of the corresponding quantities for a conventional central system with equal heating and cooling capacity. The annual average operating and administration cost for this HP-ICES is less than 70 percent of the corresponding costs for the conventional system, while the initial cost of the HP-ICES is 70 percent larger than that of a conventional system.

In the Boston case study, it was found that the annual source energy input for this HP-ICES is 35 percent and energy cost is about 30 percent of the corresponding quantities for the conventional system. The annual average operating and administration cost for this HP-ICES is 41 percent of the conventional system cost while the initial cost for this HP-ICES is 4.5 times as great as that for the conventional system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ECONOMIC EVALUATION OF THE ANNUAL CYCLE ENERGY SYSTEM

PRIN. INVESTIGATOR: J. W. MacARTHUR

ORGANIZATION: ENERGY RESOURCES CENTER
HONEYWELL, INC.

ADDRESS: 2600 RIDGEWAY PARKWAY
MINNEAPOLIS, MN 55413

TELEPHONE NO.: (612) 378-4673

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 212,299

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 7470

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 5/22/78 **THROUGH** 10/31/79

PROJECT OBJECTIVES: To assess the economic viability of the ACES, and to determine its economic competitiveness with other more conventional heating and cooling systems. To compare the seasonal coefficients of performance of ACES with conventional systems.

PROJECT DESCRIPTION AND STATUS: The project has been completed. Computer codes were developed to simulate ACES and conventional system performance and to calculate economics of operation and were applied to single- and multi-family residential and small commercial buildings in Atlanta, Philadelphia, and Minneapolis.

In brief, the full ACES was found to be the most energy efficient system evaluated for single- and multi-family dwellings, but at a cost that is unacceptable for systems installed at 1978's prototype prices. However, under a reduced equipment price scenario (projected 1982), the economic picture was very favorable.

In commercial applications, the ACES was, again, found to deliver significant energy savings and was economically superior to oil, gas, and electric systems at 1978 equipment and fuel prices in all locations.

This work has been reported in: "Economic Evaluation of the Annual Cycle Energy System (ACES)," ORNL/Sub-7470/1-VI-3, May 1980, and is available from NTIS.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF THE CONCEPT OF A SPLIT ICE-MAKER, AIR-EVAPORATOR HEAT PUMP FOR USE IN AN ANNUAL CYCLE ENERGY SYSTEM

PRIN. INVESTIGATOR: M. H. SOMMERVILLE

ORGANIZATION: UNIVERSITY OF NORTH DAKOTA (ENGINEERING EXPERIMENT STATION)

ADDRESS: BOX 8164, UNIVERSITY STATION
GRAND FORKS, ND 58202

TELEPHONE NO.: (701) 777-3132

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 232,043

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 7434

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 12/01/77 **THROUGH** 1/31/81

PROJECT OBJECTIVES: To develop a split air-water evaporator for residential ACES; to instrument and monitor two ACES demonstration houses in the Grand Forks, ND area.

PROJECT DESCRIPTION AND STATUS: The project has been completed. Three types of multiple-source heat pumps were designed and tested. They were (1) the parallel evaporator, (2) the series evaporator, and (3) the parallel evaporator with active subcooling. The parallel evaporator with active subcooling was, by far, the most promising, and in addition to its applicability to ACES, offers a potential solution to the problem of defrosting of air evaporators. A system with the parallel evaporator with active subcooling is currently under test in a home in Crookston, Minnesota. Results of this investigation are reported in: "The Design and Development of a Split Evaporator Heat Pump System," ORNL/Sub-7434/1, available from NTIS.

Two other reports resulted from this work, and they are: (1) C. P. Kipp, "Annual Cycle Energy System (ACES) Impact Upon a Utility's Load Duration Curve," 80-EES-12-01, December 1980; and (2) D. V. Mathsen, "A Summary of Monitoring Efforts and Results from the ACES-Equipped Larimore, North Dakota, and Crookston, Minnesota, Houses," 80-EES-12-03, December 1980.

Both reports are available from the Engineering Experiment Station, University of North Dakota, Grand Forks, North Dakota 58202.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ACES CONTROL PACKAGE

PRIN. INVESTIGATOR: A. G. BAITZ

ORGANIZATION: ROBERTSHAW CONTROLS COMPANY

ADDRESS: 1701 BYRD AVENUE
P.O. BOX 26544
RICHMOND, VA 23261

TELEPHONE NO.: (804) 282-9561

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 9,590

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 19X-14290V

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 8/10/77 **THROUGH** 2/21/80

PROJECT OBJECTIVES: To design and build an ACES control package for a single-family residence, with the package to serve as a prototype unit for possible commercial production.

PROJECT DESCRIPTION AND STATUS: The project has been completed. The subcontractor designed, constructed, and delivered a prototype unit for the year-round control of a minimum ACES in a single-family residence. The package consists of control closure input sensors, a central clock and logic box, and contact closure electromechanical relays for operation of output devices. Also delivered was a manual control box for checking logic box and ACES operation.

A manual describing the system, specifications, installation, operation, checkout, sensor literature, and instructions, drawings, and a parts list was supplied.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: INVESTIGATION OF ALTERNATE TYPES OF WATER STORAGE COMPONENTS TO BE UTILIZED IN CONJUNCTION WITH THE ACES

PRIN. INVESTIGATOR: I. G. CANTOR

ORGANIZATION: THE OFFICE OF IRWIN G. CANTOR

ADDRESS: 919 THIRD AVENUE
NEW YORK, NY 10022

TELEPHONE NO.: (212) 486-9450

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 12,169

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 19X14233V

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 2/24/77 **THROUGH** 1/31/78

PROJECT OBJECTIVES: To determine the cost and availability of water storage tanks suitable for an ACES installation.

PROJECT DESCRIPTION AND STATUS: The project has been completed. The subcontractor conducted research on the cost and availability of water storage tanks suitable for ACES installations and found that the most commonly used tank structures, such as wood stave and welded steel, are the least economical construction materials for such use. Field-erected construction procedures, using locally available materials and field experience, was found to be the most economical answer to tank requirements. The subcontractor concluded that integration of the ACES tank with the total house design was essential for economical development of ACES, and that the use of the tank as a portion of the foundation walls indicated as much as 50% could be saved in total tank cost.

Results of this work have been reported in "Investigation of Alternate Types of Water Storage Components to be Utilized in Conjunction with the ACES System," ORNL/Sub-78/14233/1, available from:

ACES Program
Oak Ridge National Laboratory
P.O. Box Y, Bldg. 9102-2
Oak Ridge, TN 37830

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: AID IN THE DEVELOPMENT OF AN ACES DESIGN HANDBOOK FOR LARGE BUILDINGS

PRIN. INVESTIGATOR: R. G. WERDEN

ORGANIZATION: ROBERT G. WERDEN & ASSOCIATES, INC.

ADDRESS: JENKINTOWN, PA 19046

TELEPHONE NO.: (215) 885-2500

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 237,464

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 7225

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 11/15/76 **THROUGH** 10/31/79

PROJECT OBJECTIVES: To assist Oak Ridge National Laboratory to develop an ACES design handbook for large buildings, and to provide consultation to DOE and the ACES program on HVAC systems in large buildings.

PROJECT DESCRIPTION AND STATUS: The project was terminated in October 1979 following a DOE decision to not pursue ACES applications to larger buildings at that time. At the time of termination, considerable information on hardware had been gathered and design methodologies were being developed. This information is currently being retained should interest in this concept be revived.

In addition to handbook development, the subcontractor acted as technical liaison with the Southern States Energy Board and the State of Maryland in a project, later dropped, to put an ACES in a State Office Building. This involved, among other things, an analysis of the performance and economics of three ACES configurations in three candidate office buildings. The subcontractor also provided consultation on numerous occasions to ORNL and to DOE headquarters on questions pertaining to HVAC systems in larger buildings.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ACES FEASIBILITY AND COMMERCIALIZATION

PRIN. INVESTIGATOR: D. W. TALBOTT

ORGANIZATION: NATIONAL ASSOCIATION OF HOME-BUILDERS RESEARCH FOUNDATION

ADDRESS: 627 SOUTHLAWN ROAD
P.O. BOX 1627
ROCKVILLE, MD 20850

TELEPHONE NO.: (202) 762-4200

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 88,157

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: EC-77-C-05-2130

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 9/01/76 **THROUGH** 2/28/79

PROJECT OBJECTIVES: To evaluate ACES applicability by climate and house type, and to compare energy costs for ACES and conventional systems.

PROJECT DESCRIPTION AND STATUS: The project has been completed. NAHBRF concludes that significant energy savings using ACES can be shown for all house types in all of the 16 climatic zones. They calculated that ACES energy savings at current (1978) rates would justify first costs of ACES installations ranging from $5,800 to $7,500, and that, if first costs could be brought within this range, the market potential for ACES may approach one-half million units per year.

Five potential barriers to implementation were recognized: (1) financing the higher capital cost; (2) lack of product reliability experience; (3) experienced suppliers/installers; (4) non-availability of turn-key systems; and (5) local acceptance of innovation.

This work has been reported in: "Research Program on the Economic Feasibility and Commercialization Potential of ACES," ORO/2130/1, February 1979, which is available from:

ACES Program
Oak Ridge National Laboratory
P.O. Box Y, Bldg. 9102-2
Oak Ridge, TN 37830

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: TECH COMPLEX

PRIN. INVESTIGATOR: B. A. McGRAW

ORGANIZATION: UNIVERSITY OF TENNESSEE (ENERGY ENVIRONMENT AND RESOURCES CENTER)

ADDRESS: KNOXVILLE, TN 37916

TELEPHONE NO.: (615) 974-4251

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 190,846

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: S 4457

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 9/01/75 **THROUGH** 9/30/85

PROJECT OBJECTIVES: To design and construct, at the TECH site in Knoxville, two identical residences for the field evaluation and development of innovative residential energy conversion equipment. To provide operation, maintenance, and utility services to the site, to maintain grounds, and to provide tour guides.

PROJECT DESCRIPTION AND STATUS: The two residences were constructed in 1975/76, and the remaining services have been provided on a continuing basis.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ANNUAL CYCLE ENERGY SYSTEM IMPLEMENTATION

PRIN. INVESTIGATOR: R. E. MINTURN

ORGANIZATION: OAK RIDGE NATIONAL LABORATORY

ADDRESS: P.O. BOX Y
OAK RIDGE, TN 37830

TELEPHONE NO.: (615) 574-5213

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 3,955,000 (for in-house)

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: W-7405-eng-26

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 7/01/75 **THROUGH** CONTINUING

PROJECT OBJECTIVES: To incorporate in a practical system the outstanding energy conservation potential that exists when the uni-directional heat pump and the interseasonal storage of energy are combined to provide heating, cooling, and domestic hot water to buildings. The system is to be developed and tested, its applicability to different geographic areas is to be determined, and the methodology for designing such systems is to be made freely available to the private sector.

PROJECT DESCRIPTION AND STATUS: Work under this project is concentrated in four areas: (1) field testing and development; (2) laboratory R&D; (3) systems analysis; and (4) program management. The field testing of ACES and other heat pump systems has been carried out at the TECH site on the University of Tennessee Campus in Knoxville, Tennessee. Built in 1975-76, the two houses at the site provide for carefully controlled, very-well-instrumented experiments on residential HVAC systems. For four years performance data on the Annual Cycle Energy System, on an all-electric system, and on two heat pump systems, one middle-of-the-line and the other advanced, have been gathered and analyzed. A weather station on site allows performance data to be correlated with actual weather conditions. The sophisticated data acquisition system on site has been made available to the University of Tennessee for the analysis of the performance of several active and passive solar energy systems. Current experiments involve the evaluation of frosting, defrosting, and cycling losses and the use of a desuperheater water heater in conjunction with air-to-air heat pumps, and the evaluation of ground-coupled heat pumps using buried horizontal coils.

The laboratory work has involved the development of ice-maker heat pumps for ACES application, and the evaluation of low-temperature solar panels as alternative energy sources for heat pump systems. The systems analysis work has resulted in the development of computer programs that accurately simulate the performance of a number of HVAC systems under actual weather conditions, and has allowed performance and economics of these systems to be estimated for 115 U.S. cities for which good weather data exist. The systems analysis work is being extended to evaluate other innovative systems as a tool for effective program planning.

Program Management has been concerned with the monitoring of ACES-related subcontracts and with the implementation of ACES on a national scale. In its four areas of interest, the ACES project has generated 17 technical reports and numerous papers.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	Compressor selected to meet building load
WORKING FLUID/HEAT SOURCE/HEAT SINK:	Freon/water/air
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	110/20
STEADY-STATE C. O. P. AT DESIGN TEMP.:	heat: 2.6 (32°F)/cool: 20.0 (from stored ice)

SECTION 6

PROJECTS ON GENERIC RANKINE CYCLE TECHNOLOGY

(9 PROJECTS)

PROJECT SUMMARY

PROJECT TITLE:

COMPRESSOR IMPROVEMENTS FOR HEAT PUMPS

PRIN. INVESTIGATOR: John W. Andrews

ORGANIZATION: Brookhaven National Laboratory

ADDRESS: Department of Energy and Environment
Upton, NY 11973

TELEPHONE NO.: (516) 282-7726

SUBCONTRACTOR: (if applicable) David N. Shaw

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP2033-10

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 5/1/82 **THROUGH** 6/30/83

PROJECT OBJECTIVES:

This project has two principal objectives:

- To demonstrate the capacity and COP increases -- particularly for high-lift (e.g., low-source temperature) conditions -- which have been predicted for the scavenge cycle, and
- To demonstrate the feasibility of capacity modulation, using brushless DC motors, maintaining high motor efficiency.

PROJECT DESCRIPTION AND STATUS:

The project includes development, equipment fabrication, testing, analysis, and evaluation of:

- A scavenge heat cycle modification to a reciprocating compressor, and
- Use of a variable-speed brushless DC motor.

A twofold modification of heat pumps is required. The first modification consists essentially of removal of refrigerant flash gas by means of a special expansion valve/heat exchanger combination at a pressure and temperature higher than those of the evaporator. This vapor is then directed over the motor and into the compressor cylinders through ports which are uncovered as the pistons pass through bottom dead center. The second modification is the substitution of a brushless DC motor for the AC motor. Brushless DC motors with electronic commutation have the advantage of high efficiency and very long life. Additionally, speed modulation can be achieved, with the same electronics that effect commutation, over a wide power range not easily achieved with AC induction motors.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

HYDRONIC HEAT PUMPS

PRIN. INVESTIGATOR: David A. Ball

ORGANIZATION: Battelle Columbus Laboratories

ADDRESS: 505 King Avenue
Columbus, OH 43201

TELEPHONE NO.: (614) 424-4901

SUBCONTRACTOR: (if applicable) Battelle Frankfurt
Honeywell, Inc.

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP2033-6

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 4/15/82 **THROUGH** 4/14/83

PROJECT OBJECTIVES:

The purpose of this project is to investigate the technical and economic potential of hydronic heat pumps and to perform a preliminary market identification survey. The project also seeks to determine future research requirements in this technology. Potential benefits of hydronic heat pumps include:

- Reduced heating costs to users of hydronic systems,
- A utility load levelling option when coupled with thermal storage, and
- Conservation of oil and reduction in foreign oil dependence.

PROJECT DESCRIPTION AND STATUS:

This project is a feasibility analysis of heat pumps for retrofit, add-on, and new construction with hydronic heating systems in residential and light commercial applications. The study includes:

- A survey of the relevant literature and available equipment,
- Development and analysis of concepts,
- Simulation of hydronic heat pump system performance,
- Evaluation of economics and market potential, and
- Preparation of a plan for further research and development.

Approximately 18% of existing homes are heated with hydronic heating systems, and many of these are oil-fired. Almost none of these systems use heat pumps, although a market has been developing for heat-only hydronic heat pumps in Europe. Over 50,000 such systems were installed in Europe, mostly in West Germany, by the end of 1980 typically as hybrid systems with oil-fired boilers.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

EXAMINATION OF NON-AZEOTROPIC MIXTURE REFRIGERANTS FOR HEAT PUMPS

PRIN. INVESTIGATOR: David A. Didion

ORGANIZATION: National Bureau of Standards

ADDRESS: U.S. Department of Commerce
Washington, DC 20234

TELEPHONE NO.: (301) 921-2994

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:

James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP2033-8

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 1/1/82 **THROUGH** 8/31/83

PROJECT OBJECTIVES:

The objective of this contract is to develop a simulation model of a vapor compression cycle operating with binary non-azeotropic refrigerant mixtures and to perform a parametric evaluation of performance advantages of non-azeotropic mixtures.

PROJECT DESCRIPTION AND STATUS:

Conventional vapor-compression heat pumps employ single-component refrigerants or azeotropic mixtures of refrigerants as their working fluids. Azeotropic mixtures function essentially as single-component refrigerants because their vapor- and liquid-phase compositions are the same at a given pressure. In non-azeotropic mixtures, the concentrations of individual components vary by state of the fluid in the working range. At condenser and evaporator conditions, the vapor is richer than the liquid in the more volatile component. The resultant effect is that non-azeotropic mixtures provide a performance advantage over single-component refrigerants or azeotropes. Three tasks to develop the methods and perform an examination of non-azeotropic mixture refrigerants for heat pump are included:

- Thermodynamic modelling of refrigerant mixtures,
- Heat transfer modelling of mixtures in heat pump cycles, and
- Examination of heat pumps using non-azeotropic mixtures.

The modelling efforts will take advantage of coordinated National Bureau of Standards (NBS) sponsored experimental programs involving physical measurements of mixtures. The algorithms developed will be incorporated into the NBS physical heat pump model. Candidate binary mixtures will be evaluated on seasonal performance and demand bases.

Binary non-azeotropic mixtures are the focus of a number of current non-EPRI research and development efforts. A major chemical supplier (DuPont) has recently introduced a new developmental refrigerant mixture of R13B1 and R152A that extracts more heat from cold outdoor air than common heat pump refrigerants such as R22. The resultant performance improvement provides both energy and peak demand savings by reduction of supplemental electric resistance heat. Data on mixtures is very limited and none of the recognized public-domain, physical principles models of heat pumps presently accomodate non-azeotropic mixtures.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: REFRIGERANT MIXTURE MEASUREMENTS IN TWO PHASE FLOW

PRIN. INVESTIGATOR: Dr. David Didion

ORGANIZATION: National Bureau of Standards

ADDRESS: Room B128, Building 226
Washington, D.C. 20234

TELEPHONE NO.: (301) 921-2994

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 150,000 (FY 1982)

SOURCE(S)	LEVEL (%)
NBS	100%

CONTRACT NO.: 745-1111
745-1278

CONTRACT AGENCY: National Bureau of Standards

CONTRACT PERIOD:

FROM October, 1981 **THROUGH** Continuing

PROJECT OBJECTIVES: The objective of this project is to design and construct a facility with which the heat transfer coefficient in two phase flow of fluid mixtures may be measured. A long range objective is to provide a data base and develop a method for predicting forced convection evaporative and condensing heat transfer coefficients of mixtures based on the transport and thermodynamic properties of their components.

PROJECT DESCRIPTION AND STATUS: The convective heat transfer coefficient is the single most important property for the design of heat exchangers. For those heat exchangers which have internal boiling or condensation coupled with forced convection (e.g., refrigerant systems, steam power systems, etc.), the complexity of flow conditions are such that the coefficient values are normally completely empirically based. Since this study focuses on binary mixtures which are non-azeotropic (different boiling/condensation points), the problem is complicated even further. In single component fluids it is typical to establish an empirically-based functional relationship between the convective heat transfer coefficient and the other transport properties (e.g., conductivity, viscosity, etc.) for a given range of flow patterns and thermodynamic conditions. Once these relationships are established for categories of fluids, it is possible to predict the heat transfer coefficient based on the measurements of the other transport properties which are significantly easier to make. In the area of non-azeotropic mixtures, virtually no such relationships among the transport properties exist.

The specific group of fluids that will be studied is that of fluorocarbons that are used or intended to be used as refrigerants. The apparent advantages of using non-azeotropic mixtures in refrigerant systems are (1) improvement in efficiency, (2) less environmental (ozone) impact, (3) multi-level evaporators, and (4) self lubricating working fluids. The evaluation of any of these possible advantages entails an overall performance evaluation of the refrigerant system, which in turn, requires knowledge of the transport properties of the refrigerant.

Laboratory facility is currently under construction.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

FEASIBILITY STUDY FOR VARIABLE-SPEED DRIVES FOR HEAT PUMPS

PRIN. INVESTIGATOR: Dr. N. Mohan

ORGANIZATION: University of Minnesota
Department of Electrical Engineering

ADDRESS: 123 Church Street SE
Minneapolis, MN 55455

TELEPHONE NO.: (612) 373-5419

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 895-8949

CONTRACT NO.: RP2033-4

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 10/27/81 **THROUGH** 8/31/82

PROJECT OBJECTIVES:

Conventional heat pumps achieve capacity control by cycling on and off as necessary to match the load. At part-load conditions, cycling degrades efficiency and decreases comfort. By varying compressor speed in response to heating and cooling loads, the following benefits are expected:

- Improved performance and user comfort,
- Decreased equipment wear,
- Reduced starting currents, and
- Reduced operating costs.

Higher first-costs for controls and motors may partially offset these benefits.

PROJECT DESCRIPTION AND STATUS:

This study will evaluate the feasibility of modulating heat pump capacity by compressor-motor speed variation. Six advanced alternating current (ac) motor concepts will be addressed for unitary reciprocating and rotary compressors for residential and light-commercial applications. The six concepts include:

- Square wave, voltage source inverters (VSI),
- Square wave, current source inverters (CSI),
- Pulse-width-modulated, voltage source inverters (PWM),
- Electronically-commutated synchronous motors with a permanent magnetic field (ECM),
- Pole-amplitude-modulation in induction motors (PAM), and
- High-frequency, high-speed motors using low-loss magnetic materials (HFM).

These concepts will be compared analytically against conventional and two-speed compressor motors, and requirements for further research and development will be identified if warranted.

Tests by manufacturers of two-speed compressors have confirmed the expected benefits. York has marketed a speed-modulation inverter (Turbo-Modulator) for large tonnage chillers and on a limited scale for residential applications (Enmod). A recently completed study by the University of Minnesota for EPRI (RP1201-13) examined state-of-the-art techniques for speed control of electric motors. Citing advances in semiconductor technologies, improvements in magnetic materials, and rising energy costs, the study concludes that more widespread use of variable speed motors is feasible. The study also identifies a number of concerns including introduction of harmonics and/or waveform distortion, power factor modification, phase-to-phase volume imbalance, and changes in starting torques. The study specifically recommends evaluation of variable speed drives for heat pumps.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

GROUND COUPLED/SOLAR-ASSISTED HEAT PUMP PROJECT

PRIN. INVESTIGATOR: Gerald Parker (Oklahoma State University)

ORGANIZATION: Oklahoma Gas & Electric

ADDRESS: 321 Harvey
P.O. Box 321
Oklahoma City, OK 73101

TELEPHONE NO.:(405) 624-5900

SUBCONTRACTOR: (if applicable) Oklahoma State University
Stillwater, OK. 74078

EPRI PROJECT MANAGER:
Gary Purcell
Project Manager, Solar Heating and Cooling
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-2168

CONTRACT NO.: RP1191-6

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 9/18/79 **THROUGH** 12/31/82

PROJECT OBJECTIVES: The objective is to compare the performance of a solar-and ground-assisted heat pump system, a ground-assisted heat pump system, and a conventional air-to-air heat pump system. Performance will be measured in terms of:

1. Overall life cycle costs,
2. Peak demand on the electrical system,
3. Reliability and maintenance factors,
4. kWh consumption to consumer.

PROJECT DESCRIPTION AND STATUS: This study involves a study being made on three houses located in Perkins, a community in North Central Oklahoma, served by Oklahoma Gas and Electric Company. These houses, located on adjacent lots, are identical in construction except for the HVAC systems. One has a conventional air source heat pump, one has a ground source heat pump, and one has a solar-assisted ground source heat pump. At present, all three houses are occupied by owner-families.

The houses have been instrumented and a weather station has been located in one of the back yards. All instrumentation is connected to a data collection system located in a shed attached to the exterior of the center hourse. Data are recorded on audio tape within the shed and is also available for transmission on a phone link to a small computer located on the Oklahoma State University campus.

The project has been in progress since the spring of 1979 under the support of an OG&E contract with OSU. EPRI joined in the effort in late summer of 1979 and is providing the instrumentation for the project. OG&E is furnishing the incremental costs of the HVAC systems over the conventional system and both sponsors are providing support for contract personnel at OSU, which is a subcontractor to OG&E on the EPRI contract.

Although data collection has been delayed by problems in the data logging equipment, all data logging equipment is now operational.

OG&E is a summer-peaking utility; however, because Perkins is a winter peaking community, there is considerable interest as to the peak demands of each house during periods of extreme cold. Computations have indicated that both summer and winter demand as well as energy consumption should be reduced significantly in the houses that are ground coupled.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: MULTIPLE SLIDE SCREW COMPRESSOR

PRIN. INVESTIGATOR: JOSEPH A.L.N. GAGNON

ORGANIZATION: DUNHAM-BUSH, INC.

ADDRESS: 179 SOUTH ST.
WEST HARTFORD, CT. 06110

TELEPHONE NO.: (203) 249-8671

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 627,151

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-79CS30035

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM Sept. 1979 **THROUGH** Feb. 1982

PROJECT OBJECTIVES: The objective of this project is to develop the best possible compressor for use in Series Solar Heat Pump Dystems. The compressor must be able to operate at extremely high efficiency levels from a compression ratio as low as 1.5 up to a compression ratio as high as 6.5. The compressor must have the capability to efficiently adjust to the widely varying inlet flow requirements as dictated by the operating conditions of the Series Solar Heat Pump System.

PROJECT DESCRIPTION AND STATUS: The overall project is broken into three distinct phases which are as follows:

Phase I consists of the continued development testing of a research machine to optimize the mechanical design of the overall concepts involved. Phase I also involves the development of estimated performance maps for the final machine. The design of the final machine is based upon what is learned in Phase I.

Phase II involves the design of a 25 ton (heating) Helical Screw Type Compressor which will accomplish the project objectives as stated above. The compressor will have variable inlet flow capability, variable compression ratio capability, and intermediate level vapor injection capability.

Phase III encompasses the building, testing and performance mapping of the 25 ton compressor which was designed during Phase II.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 300,000 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-22 Solar-Ground-Air/Air-Water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 120°/50°

STEADY-STATE C. O. P. AT DESIGN TEMP.: 5.3

PROJECT SUMMARY

PROJECT TITLE:

STEADY-STATE PERFORMANCE CHARACTERISTICS OF LATENT HEAT TES/HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: R. A. WHISNANT
and
T. W. SIGMON

ORGANIZATION: RESEARCH TRIANGLE INSTITUTE

ADDRESS: P. O. BOX 12194
RESEARCH TRIANGLE PARK, NC 27709

TELEPHONE NO.: (919) 541-5878

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 325,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC-01-79ET-26707

CONTRACT AGENCY: OFFICE OF ADVANCED CONSERVATION TECHNOLOGIES (DOE)

CONTRACT PERIOD:

FROM JULY, 1979 **THROUGH** JULY, 1981

PROJECT OBJECTIVES: To determine the relative viability of various coupled latent heat thermal energy storage (TES) heat pump systems for residential space heating and cooling applications and to describe the sensitivity of their relative viability to selected geographic, economic, and system performance parameters.

PROJECT DESCRIPTION AND STATUS: Two current projects are currently being completed that wholly or in part address various technical issues involved in the implementation of heat pump systems combined with TES.

The first of these involves the determination of steady state performance characteristics for six generic TES/heat pump configurations and the comparison of the operational performance of these systems with other space heating and cooling TES technologies. Of these latter systems four are commercial or near commercial air conditioner or heat pump coupled TES systems. Steady state performance has been established for all systems. Operational performance and system life cycle cost has been determined for the six generic designs for a limited set of application conditions. Operational performance is being established through use of a computer simulation which utilizes a control algorithm to identify appropriate modes of operation under a time-of-day (TOD) electric utility rate structure. This software package is presently being used to compute operational performance for the other systems considered.

The intent of the second project is to establish a reliable method of estimating seasonal energy use by TES/heat pump systems, to utilize this methodology to evaluate a large number of possible system designs, identify a small number of systems that merit more detailed analysis, and, to the extent possible, conduct these detailed studies. The approach developed to evaluate performance is a modification of the bin analysis approach. This has been completed and is presently being applied to a number of system designs.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: HEAT PUMP R&D AT OAK RIDGE NATIONAL LABORATORY

PRIN. INVESTIGATOR: F. A. CRESWICK and R. D. ELLISON

ORGANIZATION: OAK RIDGE NATIONAL LABORATORY

ADDRESS: POST OFFICE BOX Y
OAK RIDGE, TENNESSEE 37830

TELEPHONE NO.: (615) 574-2009 FTS 624-2009

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 2,250,000

SOURCE(S)	LEVEL (%)
DOE	100%

CONTRACT NO.: W-7405-eng-26

CONTRACT AGENCY: Department of Energy

CONTRACT PERIOD:

FROM FY 1976 **THROUGH** Continuing

PROJECT OBJECTIVES:

The objective of this program is to develop technology, concepts, and design tools to improve the performance, reliability, and cost-effectiveness of heat pumps using air or alternative heat sources such as well water or earth-coupled heat exchangers.

PROJECT DESCRIPTION AND STATUS:

Work is conducted in this program in four principal research areas: (1) development of analytical tools for heat pump design optimization; (2) characterization of dynamic performance losses due to cycling, frosting, and defrosting; (3) evaluation of the performance and economics of alternative heat sources; and (4) exploration and evaluation of alternative heat pump thermodynamic cycles. This program complements program-management activities at ORNL and projects conducted by subcontractors to ORNL.

Laboratory experiments were conducted to develop a data base on heat-pump component and system performance. Concurrently, a heat pump computer model was formulated with the aid of component performance data and verified against observed system performance. A design optimization technique was demonstrated in which the computer model was coupled with an optimization routine to determine the configuration for best steady state performance. This capability is being expanded to enable optimization on seasonal performance.

Field performance studies with two conventional air-source heat pumps have returned values for monthly and seasonal COPs. Additional instrumentation has been installed to determine separately cycling, frosting, and defrosting losses. Laboratory experiments have been conducted to determine frosting rate as a function of air temperature and humidity. Preparations for laboratory cycling tests are in progress.

Steady-state and cycling tests on a water-source heat pump have been run in the laboratory. A single deep vertical earth heat exchanger has been installed outside the laboratory for ground-coupling experiments. Results will be compared with analytical predictions by ORNL of the coil performance.

Analytical studies have been conducted for a variety of air-cycle heat pumps; none of these were highly promising. Modeling studies of a Stirling heat pump have thus far been encouraging. Other alternative cycles will be investigated.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

Not applicable

SECTION 7

PROJECTS ON HEAT ENGINE-DRIVEN SYSTEMS

(29 PROJECTS)

SUB-SECTIONS :

7.1 NON-RANKINE PRIME MOVER

7.2 RANKINE PRIME MOVER

PROJECT SUMMARY

PROJECT TITLE: Stirling Cycle Applicate Study

PRIN. INVESTIGATOR: Ken Hansen

ORGANIZATION: General Electric

ADDRESS: P.O. Box 8661
Philadelphia, Pennsylvania 19101

TELEPHONE NO.: (215) 962-2000

SUBCONTRACTOR: (if applicable) NA

TOTAL FUNDING: $ Not Available

SOURCE(S) **LEVEL (%)**

CONTRACT NO.: 5081-345-0534

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 9 months

FROM January 1982 **THROUGH** September 1982

PROJECT OBJECTIVES: The objective of this project is to assess the application of "Stirling Cycle" technology to the spectrum of thermodynamic machines (engines, coolers, heat pumps, etc.) that can be activated by the external combustion of natural gas, especially in ways that utilize energy more efficiently and exhibit improved performance characteristics over present methodologies.

PROJECT DESCRIPTION AND STATUS: The majority of product oriented Stirling engine developments in the United States are focused on three major areas; auto engines, electric power generation and space conditioning. To date there has been no effort to determine if these applications are the most suitable to the types of Stirling engines now available. Specifically there may be a range of other potential Stirling engine applications which may prove to be more economical, receive wider acceptance and experience earlier commercialization than those now under investigation. The project proposed by G.E. would resolve these concerns.

G.E. will perform a survey of the state-of-the-art in Stirling engine technology and establish a classification system for grouping the engines according to specific type and power. Following this, a study of possible applications will be made from some of the data compiled over the past few years. Key application parameters such as hours of operation per year, emissions, noise and environment will be used to evaluate the suitability of engine types. Power requirements for applications in apartments, shopping centers, and commercial buildings will be identified. Certain characteristic applications will be studied in depth in order to achieve a proper understanding of the requirements involved. Performance, projected costs, and operating characteristics will be optimized by adapting a conceptualized design to these particular applications.

Good energy price scenarios have been made in the past for use in analyzing the gas-fired heat pump market. These will be updated and revised to arrive at a consensus projection for the cost of various energy forms over the next decade. This projection will be used to evaluate the market potential of the Stirling engines used in the characteristic applications mentioned above.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NA
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ANALYTICAL STUDY OF LIQUID PISTON HEAT PUMP TECHNOLOGY

PRIN. INVESTIGATOR: J. GERSTMANN

ORGANIZATION: ADVANCED MECHANICAL TECHNOLOGY, INC.

ADDRESS: 141 CALIFORNIA STREET
NEWTON, MA 02158

TELEPHONE NO.: (617) 964-2042

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 41,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: 31-109-38-6506

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM AUGUST 15, 1981 **THROUGH** AUGUST 31, 1982

PROJECT OBJECTIVES: Demonstrate the feasibility of a liquid piston heat pump operating on a Stirling cycle.

PROJECT DESCRIPTION AND STATUS: This program has the following two tasks:

- Task 1 — Develop Second-Order Model
- Task 2 — Develop Component Models and Effects

Work performed includes the development and testing of an isothermal and adiabatic second-order cylinder model. The isothermal model has been successfully implemented and verified against a linear code. The adiabatic model has been implemented but test results indicate that model refinements are required before the code is operational. Work completed under Task 2 includes the formulation of a shuttle heat transfer model.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

not applicable

PROJECT SUMMARY

PROJECT TITLE: ADVANCED HEAT-EXCHANGER TECHNOLOGY DEVELOPMENT

PRIN. INVESTIGATOR: DR. A. FEJER

ORGANIZATION: INSTITUTE OF GAS TECHNOLOGY

ADDRESS: 3424 S. STATE ST.
CHICAGO, IL 60616

TELEPHONE NO.: (312) 567-5734

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 28,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: 31-109-38-6551

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM AUGUST, 1981 **THROUGH** DECEMBER, 1981

PROJECT OBJECTIVES: To examine the technological issues of closed cycle gas turbine systems principally related to heat exchangers and combustors, and to investigate further the concept of a total energy system which uses turbo-machinery to provide varying heating, cooling, and electrical loads.

PROJECT DESCRIPTION AND STATUS: An analytical study program is being conducted by IGT to investigate improvements in gas-to-gas heat-exchanger technology for use in external-combustion heat engines. This study is expected to produce a preliminary design for an advanced oil or gas-fired heat-exchanger for use in a Compound Heat Pump Gas Turbine (CHPGT) using cogeneration techniques. The work has the following tasks:

1) Identification of the state-of-the-art in gas-to-gas heat-exchanger technology.
2) Identification of typical CHPGT application. Determination of the design requirements for the application identified.
3) Determination of the necessary technology advancements to state-of-the-art designs to meet requirements of Task 2.
4) Conceptual design of radiant/convective and fluidized-bed heat exchangers for the application of Task 2.
5) Analysis of the conceptual heat-exchanger design and selection of a configuration for a design study.
6) Design study of the selected externally fired heat-exchanger.
7) Outline and discussion of studies required for final heat-exchanger design.

A report was issued which provided an assessment of current and improvements to CHPGT heat-exchanger technology and the analysis of a representative non-site-specific CHPGT applicator. Continuation of this program is expected in 1982.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: Free-Piston Stirling Engine Technology Development

PRIN. INVESTIGATOR: George R. Dochat

ORGANIZATION: Mechanical Technology Incorporated

ADDRESS: 968 Albany-Shaker Road
Latham, New York 12110

TELEPHONE NO.: (518) 456-4142

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 188,000

SOURCE(S)	LEVEL (%)
DOE - Argonne National Laboratory	100%

CONTRACT NO.: 31-109-38-6420

CONTRACT AGENCY: Argonne National Laboratory

CONTRACT PERIOD:

FROM July 1, 1981 **THROUGH** December 31, 1981

PROJECT OBJECTIVES: The objective of this program is to gain an improved understanding of free-piston and Stirling engine technology by providing both analytical and experimental evaluation of specific loss mechanisms within the engine during operation. This improved understanding of basic engine processes will lead to increased performance capability and, therefore, have direct benefit in the development of heat-activated heat pumps, fluid pumps, and engine-generator sets.

PROJECT DESCRIPTION AND STATUS: The present project is a continuation of an R&D effort initiated by DOE/Nuclear. This project was transferred to DOE/Fossil and then to DOE/Conservation.

The 1 kW free-piston Stirling technology demonstrator engine has been built and operated. Past efforts have focused on getting the engine to the point of development where meaningful tests can be conducted. It is currently viewed that free-piston Stirling engine driven heat pumps are candidate viable options with engine sizes in the 1 to 10 kW range.

The current project will utilize the Technology Demonstrator Engine (TDE) system, which is a 1 kWe free-piston Stirling engine/linear alternator, as a test bed to evaluate specific loss mechanisms within the engine. The specific loss mechanisms to be evaluated include compression space hysteresis, regenerator, displacer clearance seal, and displacer gap. The evaluation will include the current analytical procedures for calculating the specific losses, perform a series of tests to isolate each loss, compare actual performance with predicted performance, and determine adequacy of present analytical methods.

Currently, the TDE has been developed such that it qualifies as the test bed for this program. The TDE has the necessary and sufficient instrumentation, flexibility of design dynamics, wide range of test capabilities, ability to modify design and incorporated changes, and validated analytical codes; therefore, it can be utilized in specific loss experimental evaluation.

Initial baseline performance testing will be performed in early July. This test will provide the baseline data against which specific loss tests will be compared.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS) Technology Development/not applicable

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: Natural Gas Heat Pump Field Demonstration

PRIN. INVESTIGATOR: Dr. Shelton

ORGANIZATION: Georgia Tech

ADDRESS: Administration Building
Georgia Institute of Technology
Atlanta, Georgia 30332

TELEPHONE NO.: (404) 894-3289

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ Not Available

SOURCE(S) **LEVEL (%)**

CONTRACT NO.: 5081-341-0503

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 1½ years

FROM June 1981 **THROUGH** December 1982

PROJECT OBJECTIVES: The objective of this project is to demonstrate the feasibility and cost effectiveness of operating an internal combustion (IC) gas-fired heat pump in a residential application.

PROJECT DESCRIPTION AND STATUS: The heat pump to be used in this project is a 1.4 litre, European Ford, four cylinder engine coupled to a West German compressor. Engine optimization for stationary heat pump operation has been the primary thrust of the packaged space conditioning unit. Near term commercialization (1982) and high efficiency performance (COP_C, 0.85-1.0; COP_H, 1.5-1.8) represent the major advantages of this equipment. Emphasis will be placed on determining the actual performance, maintenance costs, operating costs, noise level and overall economic viability of this new heat pump. This project represents the first full scale field test of this type of heat pump in the U.S. and includes the practical evaluation of a very near term engine heat pump in an American residence. The results of this project may provide GRI with valuable information relating to future GRI heat pump developments, testing and evaluation.

Atlanta Gas Light Company (AGLC) has already funded the initial evaluation and will share one-half of the cost of the field test. Site design, site modification, equipment purchase, equipment installation, and instrument setup has been completed.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 30,000 cooling, 101,000 heating

WORKING FLUID/HEAT SOURCE/HEAT SINK: Rankine Heat Pump, Air Source/Sink

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.: To be determined

PROJECT SUMMARY

PROJECT TITLE: Stirling/Stirling Heating-Only Heat Pumps - Phase II

PRIN. INVESTIGATOR: Dr. Beale

ORGANIZATION: Sunpower, Inc.

ADDRESS: 6 Byard Street
Athens, Ohio 45701

TELEPHONE NO.: (614) 594-2221

SUBCONTRACTOR: (if applicable) NA

TOTAL FUNDING: $ Not Available

SOURCE(S)	LEVEL (%)
GRI	100

CONTRACT NO.: 5081-341-0464

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 1¼ years

FROM May 1981 **THROUGH** August 82

PROJECT OBJECTIVES: The objective of this project is to demonstrate the hardware proof-of-concept for the duplex Stirling heating-only heat pump.

PROJECT DESCRIPTION AND STATUS: Sunpower has proposed a program in which they will design, fabricate and test an actual-sized prototype of the Stirling/Stirling heating-only heat pump at their facilities in Athens, Ohio. The full-scale model will be assembled, tested and gas-fired, with test results available before the end of 1982. This phase of the development is expected to verify the full-scale performance of the heating-only heat pump and provide a data base with which to approach selected manufacturers for support before going onto the next phase of the development.

The initial study concluded that a duplex Stirling heating-only heat pump could achieve a seasonal coefficient of performance of 1.59 (based on a new residence in Omaha, Nebraska). This performance figure represents a 40% energy savings over the condensing furnace concepts, and a 60% energy savings over conventional furnaces. Simple payback for the heat pump is estimated to be between 2 and 6 years, when compared to condensing furnaces.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 40,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Helium, ambient air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DUPLEX STIRLING GAS FIRED HEATING ONLY HEAT PUMP

PRIN. INVESTIGATOR: WILLIAM BEALE

ORGANIZATION: SUNPOWER INC.

ADDRESS: 6 BYARD STREET
ATHENS, OHIO 45701

TELEPHONE NO.: (614) 594-2221

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 633,449

SOURCE(S)	LEVEL (%)
GAS RESEARCH INSTITUTE	100%

CONTRACT NO.: 5081-341-0464

CONTRACT AGENCY: GAS RESEARCH INSTITUTE

CONTRACT PERIOD:

FROM MAY 1, 1981 **THROUGH** MAY 31, 1982

PROJECT OBJECTIVES: The primary objective is to construct a laboratory demonstration Duplex Stirling Heating Only Heat Pump with a 10 kW heating capacity at -8° C source temperature, and to measure its performance over a range of source temperature. Secondary objectives are to make an analytical assessment of the penalty incurred by optimization for heating and cooling in comparison to an optimization for heating only, and to refine the cost and payback time estimates made in the first analytical study.

PROJECT DESCRIPTION AND STATUS: This project is a continuation into hardware test of an initial study which resulted in a projected heating COP of over 1.5 for a Duplex Stirling Heating Only Heat Pump.

The duplex Stirling machine to be built is a bread board version of a 10 kW heat pump comprised of a gas burner, free piston Stirling engine, free piston Stirling heat pump in the same helium pressure enclosure, and the associated heat exchanges, controls and accessories comprising the complete system.

The novel features of this heat pump are its great simplicity, with only three moving parts within the pressure enclosure, absence of any flexing or sliding isolation seals, high thermodynamic performance, and complete power-load matching over the entire range of sink temperature without recourse to complex control processes.

This program builds upon 16 years of hardware experience with free piston Stirling engines and a body of simulation and optimization procedures which have resulted in many operating free piston engines including a 100 watt proof-of-principle model of the Duplex Stirling Heat Pump.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 34,000 (10 kw)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Helium (engine), glycol-water (exchanger)/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 17° F (-8° C)/122°F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.7 heating

PROJECT SUMMARY

PROJECT TITLE: DIAPHRAGM STIRLING ENGINE HEAT-ACTUATED HEAT PUMP DEVELOPMENT

PRIN. INVESTIGATOR: PAUL SWENSON

ORGANIZATION: CONSOLIDATED NATURAL GAS RESEARCH COMPANY

ADDRESS: 11001 CEDAR AVENUE
CLEVELAND, OHIO 44106

TELEPHONE NO.: (216) 421-6314

SUBCONTRACTOR: (if applicable) DR. ROBERT A. ACKERMANN

MECHANICAL TECHNOLOGY INCORPORATED

968 ALBANY-SHAKER ROAD
LATHAM, NEW YORK 12110

(518) 456-4142

TOTAL FUNDING: $ 2,813,750

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	79%
CONSOLIDATED NATURAL GAS	21%

CONTRACT NO.: 86X-6161C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM JUNE 1, 1980 **THROUGH** OCTOBER 31, 1982

PROJECT OBJECTIVES: The objective of this program is to develop and demonstrate the performance of a diaphragm Stirling engine heat-actuated heat pump power module. The power module, consisting of a free displacer, resonant Stirling engine, hydraulic transmission, and resonant Rankine refrigerant (F-22) compressor, embodies several innovative concepts in free-piston Stirling engine heat pump design that will advance the state of the art of this technology.

PROJECT DESCRIPTION AND STATUS: For the past two years Consolidated Natural Gas Research Company (CNG), together with Mechanical Technology Incorporated (MTI), has been developing a Stirling-engine-driven residential heat-actuated heat pump under the GASCON (gas conservation) program. In June 1980, DOE/ORNL became a third partner in this program, with the primary objective of developing a demonstrator engine/compressor power module based on some newly conceived and promising GASCON concepts. The key element in this new concept is the use of a hydraulic transmission that hermetically seals the engine working fluid from the compressor working fluid by a flexible metal diaphragm.

Progress has been made in three areas of the program. First, a compressor/engine matching analysis and a stability analysis have shown that the power module, which is representative of a two-degree-of-freedom resonant system, will operate stably over the full range of heat pump conditions. Second, a compressor design has evolved that has met our criteria for performance and cost; and third, tests employing a hydraulic simulator test rig has shown that the transmission losses are less than we had predicted, and that properly designed and fabricated diaphragms can attain long life.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 (cooling); 40,000 (heating @ 17°F)

WORKING FLUID/HEAT SOURCE/HEAT SINK: F-22/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 121/45°F (cooling); 117/4°F (heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.3 (cooling); 1.6 (heating)

PROJECT SUMMARY

PROJECT TITLE: ASSESSMENT OF I.C. ENGINES AS DRIVERS FOR HEAT ACTUATED HEAT PUMPS

PRIN. INVESTIGATOR: JAMES C. BURKE, W.P. Teagan, and P.G. Gott

ORGANIZATION: ARTHUR D. LITTLE, INC.

ADDRESS: ACORN PARK
CAMBRIDGE, MA 02140

TELEPHONE NO.: (617) 864-5770

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 49,222

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 62B-13836C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM May 1980 **THROUGH** December 1980

PROJECT OBJECTIVES: The objective of this program is to assess the present suitability and future potential of gas-fired and oil-fired internal combustion (I.C.) engines for use in heat-actuated heat pumps for space conditioning applications. Results of this study will be used as a resource in future program planning and will include the definition of R&D tasks that could be undertaken to improve the suitability of I.C. engine heat pump applications. The study will focus on drives for residential and light commercial machines up to 100 KW output--or approximately 50 HP engine input.

PROJECT DESCRIPTION AND STATUS: This program to assess the potential of I.C. engine heat pumps consisted of four tasks:

- Task 1 - Review prior experience with piston engine drives for small, long-term stationary applications, similar to heat pumps to understand the prior success and/or problems and the approach for minimizing such problems in future applications.
- Task 2 - Establish characteristics of current engines in terms of cost, performance, maintenance and operational features for various engine types of interest for heat pump applications.
- Task 3 - Prepare and evaluate conceptual designs of I.C. engine heat pump systems on the basis of cost, performance, economics, and operational and institutional factors to obtain a preliminary assessment of the potential of I.C. engine-driven heat pump systems.
- Task 4 - Identify program options for I.C. engine heat pump development.

The work on this program has been completed and indicated that I.C. engine heat pump systems appear sufficiently promising to warrant further development, particularly in the larger sizes applicable to multi-family and light commercial applications. Recommended development options included system demonstration, annual performance simulation, production cost projections and market analysis.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.5

PROJECT SUMMARY

PROJECT TITLE: TEST AND DEMONSTRATION OF A HERMETIC COMPRESSOR SEAL AND PHASE I, DEVELOPMENT OF A BRAUN LINEAR ENGINE-DRIVEN, HEAT-ACTUATED HEAT PUMP

PRIN. INVESTIGATOR: A.T. BRAUN (TECTONICS RESEARCH, INC.)

ORGANIZATION: HONEYWELL INC. TECHNOLOGY STRATEGY CENTER

ADDRESS: D.N. CARLSON
PROGRAM MANAGER
1700 WEST HIGHWAY 36
ROSEVILLE, MN 55113

TELEPHONE NO.: (612) 378-4162

SUBCONTRACTOR: (if applicable)
TECTONICS RESEARCH, INC.
A.T. BRAUN
PRESIDENT AND TECHNICAL DIRECTOR
9556 WEST BLOOMINGTON FREEWAY
MINNEAPOLIS, MN 55431
(612)881-2617

HONEYWELL, INC.
CORPORATE TECHNOLOGY CENTER
DR. ULRICH BONNE

TOTAL FUNDING: $2,144,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100
HONEYWELL INC.	33 (Additional)

CONTRACT NO.: SEALS: 86X 61613C
PHASE I: 86X 61619C

CONTRACT AGENCY: UNION CARBIDE NUCLEAR DIVISION

CONTRACT PERIOD:

FROM MARCH 26, 1980 **THROUGH** MARCH 31, 1982

PROJECT OBJECTIVES: The objectives of the two projects are to develop and demonstrate a viable hermetic seal; to advance the state of development, through analyses, simulation, design, fabrication and testing, of the key elements and components of the Braun linear engine/compressor so that it becomes a sound basis for a reliable light-commercial-sized heat pump system; to develop and evaluate integral heat recovery and defrost systems; to develop necessary controls; and to develop preliminary prototype heat pump system specifications.

PROJECT DESCRIPTION AND STATUS: This is a new R&D project, although it is based on substantial prior research and development. The BR-105 Braun linear engine/air compressor upon which this project is based is already highly developed, with over 45,000 hours of running time and testing. An alternate version, the BR-300 Braun linear engine/Freon compressor, has been operated in both heating and cooling modes with a 20-ton commercial heat pump system.

In this heat-actuated heat pump application, the cooling and exhaust heat of the engine/compressor is also being utilized for heating, along with the heat from the air-to-air Freon compressor loop. The brake efficiency of the Braun engine operating in the spark ignition (SI) mode has been measured at 34 percent after accounting for all compressor losses up to the compressor piston itself. Additional SI efficiency improvement is expected. Exceptionally high COP, even at low outdoor temperatures, is predicted.

The major part of the seal program has been completed. Proprietary hermetic seals of infinite life design have been investigated and demonstrated for practical stroke lengths and cyclic speeds. These results have been carried forward into the Phase I program for integration into the Braun linear engine/Freon compressor.

During the recently initiated Phase I program, parallel development and interfacing of the various components are being carried forward, such as hermetic seals; refrigerant compressor (with valves, seals, etc.); BR-105 engine (fuel injection, ignition, starting, speed control, stroke control, etc.); controls (engine and compressor interface, system response to environment, etc.).

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 (cooling); 90,000 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Freon R-22/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95°F outdoor for cooling; U.S. seasonal average for heating

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.4 cooling; 2.2 heating/ seasonal prime energy efficiency assuming gravity heat exchanger system and 70% waste heat recovery; 50 W crankcase heater

PROJECT SUMMARY

PROJECT TITLE: LIGHT COMMERCIAL BRAYTON/RANKINE SPACE CONDITIONING SYSTEM

PRIN. INVESTIGATOR: David Friedman, Kenneth Trester, Wiley Cowell

ORGANIZATION: AiResearch Manufacturing Company

ADDRESS: 2525 W. 190th Street Torrance, California 90509

TELEPHONE NO.: (213) 323-9500

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $≈ 5,000,000.00

SOURCE(S)	LEVEL (%)
Department of Energy	39.3
Gas Research Institute	39.3
AiResearch Manufacturing Co.	21.4

CONTRACT NO.: 86X-24706C

CONTRACT AGENCY: Union Carbide Corporation

CONTRACT PERIOD:

FROM March 1979 **THROUGH** September 1982

PROJECT OBJECTIVES: The objectives of this phase of the program are to develop a (10-ton) Brayton/Rankine gas-fired space conditioning system and components, analyze the market and business potential for the product, and test prototype systems and subsystems under simulated field conditions in the laboratory.

PROJECT DESCRIPTION AND STATUS: The present program is a continuation of an R & D effort carried out initially under the sponsorship of the American Gas Association, and more recently by the Gas Research Institute and the Department of Energy.

The system presently under development consists of a natural-gas-fueled, Brayton cycle turbine engine, which drives the centrifugal vapor compressor of a Rankine cycle heat pump through a magnetic coupling. The system offers a high performance potential by utilizing the most advantageous working fluid for each cycle. An air/gas mixture is used in the heat engine, where high turbine inlet temperatures provide high thermal efficiency; and Refrigerant-12 is used in the heat pump, because of its desirable thermodynamic characteristics. Waste heat energy from the Brayton cycle engine is transferred to the building in the heating mode. Analysis indicates significant improvement in annual performance over conventional systems in all climatic regions.

Development of the major components of the system has been completed or is nearing completion. Performance targets were achieved for the items completed. Extensive breadboard system testing and system analysis also has been performed. The predicted overall efficiency of the Brayton cycle engine is 27 percent at the cooling design point, and predicted overall C.O.P. at the energy source is 1.0 and 1.2 in cooling and heating, respectively, including parasitics.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 120,000 (ARI cooling); 168,000 (ARI heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-12/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 120/50 (cooling); 104/33 (heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.0 cooling; 1.2 heating (at energy source and with parasitics included)

PROJECT SUMMARY

PROJECT TITLE: Open-Cycle Rotary Screw Steam-Compression Heat Pump

PRIN. INVESTIGATOR: R. Sakhuja and F. Becker

ORGANIZATION: Thermo Electron Corporation

ADDRESS: 101 First Ave.
Waltham, Massachusetts 02154

TELEPHONE NO.: (617) 890-8700

SUBCONTRACTOR: (if applicable)

Beloit Power Systems

TOTAL FUNDING: $ 2,587,197.00

SOURCE(S)	LEVEL (%)
GRI	67.3
Other	32.7

CONTRACT NO.: N/A

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 4-1/3 Years

FROM January 1979 **THROUGH** May 1983

PROJECT OBJECTIVES: Improvements in the cost-effectiveness of current industrial heat pump cycles (both open and closed) require technological advances in mechanical steam-compressor machines. GRI's industrial heat pump program is directed toward removing the technological barriers that inhibit the commercialization of both the open cycle and Rankine Cycle heat pump systems. The objective of this project is to develop and commercialize an open-cycle steam-compression heat pump that takes advantage of the rotary screw compressor's unique ability to recompress wet and contaminated waste steam while overcoming inherent size limitations.

PROJECT DESCRIPTION AND STATUS: The system utilizes excess low-pressure steam or that produced from an excess heat source with a waste heat boiler and compresses this steam to the desired pressure level for process use. The compressor is driven by a gas fired prime mover such as a gas turbine or gas engine. To enhance the system performance, the prime mover exhaust and cooling jacket heat is recovered to generate additional process steam or hot water. The major fraction of the energy in the steam is already available to the compressor as latent heat. As a result, only a small fraction of additional energy is required to raise its pressure and temperature to a useful level. Although significant energy savings can be realized by use of the steam heat pump system, such a concept must also be justified economically. Economic analyses have shown favorable simple payback periods of one to three years depending on the nature of the excess heat or steam source, steam flow rate, pressure ratios, and fuel cost.

In the development work to date, a Proof-Of-Concept field test system has been fabricated and tested at Thermo Electron. The system includes all the major components and is of adequate size to demonstrate the performance and operating characteristics of a full-size system. The system is based on a 1.04m^3/s (2200 CFM) screw compressor with a built-in pressure ratio of 3:1. The compressor is driven by a 373 kW (500 hp), 1200 RPM industrial gas engine through a 1:7.7 ratio gearbox. The system is designed for a nominal steam flow rate of 1.26 kg/s (10,000 lb/hr) at an inlet pressure of 207 kPa (30 psia) and an outlet pressure of 621 kPa (90 psia).

A test facility was built to investigate important operating parameters of the system's modified screw compressor. The compressor was tested over a wide range of operating conditions, with experimental results showing excellent agreement with predicted performance. The compressor's operation with wet steam and water injection was completely satisfactory, demonstrating its suitability for use in a steam heat pump.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	10,000,000
WORKING FLUID/HEAT SOURCE/HEAT SINK:	steam/reject steam/determined by process
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	250/320
STEADY-STATE C. O. P. AT DESIGN TEMP.:	2.46

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT AND DEMONSTRATION OF A STIRLING/RANKINE HEAT ACTIVATED HEAT PUMP-PHASE II

PRIN. INVESTIGATOR: RICHARD C. MEIER

ORGANIZATION: GENERAL ELECTRIC COMPANY

ADDRESS: P. O. BOX 8661
PHILADELPHIA, PA 19101

TELEPHONE NO.: (215) 962-3868

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 7,573,500.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	50%
GAS RESEARCH INSTITUTE	50%
GENERAL ELECTRIC	+30% (Program Support and Ex.Scope)

CONTRACT NO.: DE-AC02-77CS20043

CONTRACT AGENCY: DEPT. OF ENERGY, CHICAGO OPER.

CONTRACT PERIOD:

FROM DECEMBER 1976 **THROUGH** JUNE 1981

PROJECT OBJECTIVES: The objectives of the current contract of Phase II of the Stirling/Rankine Heat Activated Heat Pump project are to:

- demonstrate that the performance predictions established in the Phase I program can be achieved.
- assess whether the product cost goals are attainable.

PROJECT DESCRIPTION AND STATUS: The Stirling engine driven heat pump under development in this project utilizes a natural gas combustor/Stirling engine/linear inertia compressor assembly in place of the conventional motor/compressor unit employed in electric heat pumps. Heat input from the gas combustor provides thermal energy to the Stirling engine working fluid, helium. The engine power piston is directly connected to the compressor housing with the refrigerant being compressed by a free piston reciprocating within the housing.

The current Phase II program includes the development of an engineering prototype HAHP, followed by the development and field testing of a prototype residential unit. Development and testing of the engineering prototype was completed in early 1979. All of the components and subsystems met their performance goals except for the Stirling engine. The engine achieved an efficiency of 26%, versus a goal of 30%. Empirical data from the engineering prototype was then used to design the residential unit prototype, using a third order simulation model developed for the engine/compressor. At present, development and testing of the system components and the combustor/engine/compressor subsystem has been completed, preparation for laboratory tests of the complete residential unit prototype system are underway, and installation preparations at the field test site are nearly completed. The prototype residential unit components met their goals, except again for the Stirling engine. The engine achieved indicated power and efficiency values of 2.8Kw and 27%, versus goals of 3.2Kw and 33%, respectively.

General Electric has conducted market and business assessment studies in parallel with the hardware development contract. Results of the studies indicate that the projected 3 to 5 year payback on the initial premium price of the HAHP can generate a market growth history comparable to that of central air conditioning. Industry shipments are projected at 100,000 units per year, 10 years after introduction.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 (Cooling at 95°F); 50,000+(Heating at 17°F)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-22/Air/Air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 120/49 (Cooling at 95°F); 99/31 (Heating at 47°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.0 (Cooling at 95°F); 1.9 (Heating at 47°F)

PROJECT SUMMARY

PROJECT TITLE: 1 KW KINEMATIC STIRLING ENGINE DEVELOPMENT

PRIN. INVESTIGATOR: JAMES BLEDSOE

ORGANIZATION: GENERAL ELECTRIC COMPANY

ADDRESS: P.O. BOX 8661
PHILADELPHIA, PA 19101

TELEPHONE NO.: (215) 962-1492

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 6,400,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC-0176 ET 32002

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM May 1976 **THROUGH** November 1981

PROJECT OBJECTIVES: The objective of this project is to develop a 1 kW kinematic Stirling engine. A candidate application of this engine is to be integrated into an engine driven heat pump system.

PROJECT DESCRIPTION AND STATUS: The present project is a continuation of an R&D effort initiated by DOE/Nuclear to drive a Stirling engine with an isotope power heat source. The project was transferred to DOE/Fossil and to DOE/Conservation. The isotope power heat source has been removed, but development of the engine has continued.

This engine has been built and operated successfully. The bulk integrated into the engine design because of the initial isotope power heat source has made the current engine very expensive. It is currently viewed that kinematic Stirling engine driven heat pumps are candidate viable options with engine sizes greater than 10 kW.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) Not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: Advanced Open-Cycle Centrifugal Vapor Compression Heat Pump

PRIN. INVESTIGATOR: T. Iles

ORGANIZATION: Garrett Corporation
AiResearch Manufacturing Company of California

ADDRESS: 2525 W. 190th Street
Torrance, CA., 90509

TELEPHONE NO.: (213) 321-5000

SUBCONTRACTOR: (if applicable)

Niro Atomizer, Inc.
APV Company

TOTAL FUNDING: $ 1,037,888

SOURCE(S)	LEVEL (%)
GRI	88
AiResearch	12

CONTRACT NO.: N/A

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 24 Months

FROM March 1981 **THROUGH** March 1983

PROJECT OBJECTIVES: To develop a gas turbine-driven centrifugal vapor compressor system to be used with low temperature evaporators serving as preconcentrators in a drying facility. The system intends to exploit the use as a heat source, water vapor that is exhausted from an evaporator and mechanically compressed, in the steam chest of the same evaporator. The system also intends to incorporate a single-stage centrifugal compressor used in a multi-effect evaporator manner with high temperature differentials but at the lower cost of a single stage compressor.

PROJECT DESCRIPTION AND STATUS: The compressor can increase the vapor saturation temperature up to 45°F at a design flow of 35,000 cfm. The gas turbine engine that drives the compressor is a Garrett Model 1E831-800. Equipment design will be completed in 1981; the installation design and equipment fabrication will be completed in 1982; and equipment development and concept demonstration in a milk-drying facility will be completed in 1983.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DETERMINATION OF THERMAL STABILITY OF ORGANIC WORKING FLUIDS FOR RANKINE CYCLE SYSTEMS

PRIN. INVESTIGATOR: DR. DEAN MORGAN

ORGANIZATION: THERMO ELECTRON CORP.

ADDRESS: 101 FIRST AVE.
WALTHAM, MA 02154

TELEPHONE NO.: (617) 890-8700

SUBCONTRACTOR:
(if applicable)

HARVARD MEDICAL SCHOOL

TOTAL FUNDING: $ 418,244.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: DE-AC03-80CS30220

CONTRACT AGENCY: DEPARTMENT OF ENERGY SAN FRANCISCO

CONTRACT PERIOD:

FROM SEPTEMBER 30, 1980 **THROUGH** SEPTEMBER 30, 1982

PROJECT OBJECTIVES: To determine the rate of decomposition of organic working fluids due to either pyrolytic or chemical reactions as functions of temperature and the materials in contact with the fluid, under operating conditions comparable to those occurring in Rankine engine solar applications.

PROJECT DESCRIPTION AND STATUS: This program involves the long term testing of organic fluids used and/or proposed for solar Rankine cooling systems under conditions that approximate or exceed those expected in actual operating systems.

Five identical loops are being constructed to perform the fluid testing. These loops include all of the components in an actual Rankine engine with the exception of the expander which is to be replaced with a variable orifice pressure let-down valve to reduce boiler pressure to the condenser pressure. Design considerations allow for operations at temperatures that approach thermal stability temperatures of organic fluids with the capability to operate at boiler conditions up to 750°F and 1150 psia. Working fluids to be tested in the loops include: loop 1, R-11 without lubricant; loop 2, R-11 with lubricant; loop 3, R-113 without lubricant; loop 4, R-113 with lubricant; and loop 5, R-114 without lubricant. Fluid degradation will be tested at multiple boiler outlet temperatures. Harvard University, under a subcontract, will provide the chemical analysis for measurement of fluid degradation.

Program plans call for the completion and start-up of all loops by November of 1981. No test data on the working fluids has been reported in the literature as of this summary.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: EJECTOR HEAT PUMP APPLICATIONS
(LOW GRADE HEAT RECOVERY PROJECT)

PRIN. INVESTIGATOR: HARRY G. ARNOLD
HORACIO PEREZ-BLANCO
W. R. HUNTLEY

ORGANIZATION: UNION CARBIDE CORPORATION

ADDRESS: P. O. BOX Y
OAK RIDGE, TN 37830

TELEPHONE NO.: (615) 574-5764

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 35,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: W-7405-eng-26
AA-55-15-15-0 00011

CONTRACT AGENCY: DOE, Office of Fossil Energy

CONTRACT PERIOD:

FROM July, 1980 **THROUGH** May, 1981

PROJECT OBJECTIVES: The Waste Heat Recovery Program administered by Oak Ridge National Laboratory has the objective of identifying and developing technology for recovering waste heat at temperatures below 90°C. Under this program, a variety of heat-pumping and refrigerating technologies are being developed by subcontractors. There is also an in-house effort whose overall objective is to identify, screen and develop advanced, high-risk concepts that show adequate potential for waste heat recovery. The present project had the objective of determining the technical feasibility and the economic potential of steam ejectors for low-grade waste heat recovery. Even though this technology had found in the past widespread use for thermal-recompression applications, the range of operating conditions was different from the conditions found in low grade heat recovery.

PROJECT DESCRIPTION AND STATUS: This project consisted of evaluating jet ejectors for heat pump applications. The compression ratios, temperature boosts, efficiencies, and costs were evaluated for specific industrial applications. It was found that even when recovering subatmospheric steam (~2 psia) ejectors can in some special cases provide process heat cheaply. In these special cases, it is assumed that the boiler providing motive steam is paid for, and that process steam pressure is reduced via the steam ejector. A paper summarizing this will be presented at the Houston ASHRAE meeting in January 1982.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: LOW TEMPERATURE WASTE HEAT UTILIZATION CHILLER SYSTEM

PRIN. INVESTIGATOR: SCOTT J. HYNEK

ORGANIZATION: FOSTER-MILLER ASSOCIATES

ADDRESS: 350 SECOND AVENUE
WALTHAM, MA 02154

TELEPHONE NO.: (617) 890-3200

SUBCONTRACTOR: (if applicable)

N/A

TOTAL FUNDING: $780,288

SOURCE(S)	LEVEL (%)
Department of Energy	100%

CONTRACT NO.: 41X-28906C

CONTRACT AGENCY: Oak Ridge National Laboratory

CONTRACT PERIOD:

FROM August, 1979 **THROUGH** June, 1982

PROJECT OBJECTIVES: To design, develop, and demonstrate an industrial refrigeration system to be powered primarily by the 140 F (60C) waste hot water that is available at many industrial sites as well as government owned gaseous diffusion plants. This system should maximize the ratio of refrigeration capacity to capital cost.

To investigate commercial applications of this system and to commercialize it by teaming with a manufacturer.

PROJECT DESCRIPTION AND STATUS: The waste heat driven chiller system consists of a Rankine cycle driving a reverse-Rankine cycle, integrated in that they share a common working fluid (R-22), a common condenser, and a common crankcase housing the expander and compressor. One bank of compressor cylinders is transformed into expander cylinders by replacing the head with a specially designed head containing rotary valves. A hermetically housed induction generator absorbs any surplus shaft power and provides speed control; on hot days it makes up the shaft power deficit.

The preliminary system design is complete; standard components (including condenser and compressor) have been selected and special components (such as rotary expander valve and boiler feed pump) have been designed. The boiler feed pump has been tested, and expander testing is underway. The design and construction of a complete demonstration system has begun.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 240,000 (at evaporator)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-22/brine/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95°/15°

STEADY-STATE C. O. P. AT DESIGN TEMP.: N/A

PROJECT SUMMARY

PROJECT TITLE: RANKINE/RANKINE HEAT PUMP

PRIN. INVESTIGATOR: B. MORIARTY

ORGANIZATION: MECHANICAL TECHNOLOGY INC.

ADDRESS: 968 ALBANY-SHAKER RD.
LATHAM, NY 12210

TELEPHONE NO.: (518) 785-2595

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 3,000,000.

SOURCE(S)	LEVEL (%)
GAS RESEARCH INSTITUTE	90
NEW YORK STATE ERDA	10

CONTRACT NO.: 5011-341-0149

CONTRACT AGENCY: GAS RESEARCH INSTITUTE

CONTRACT PERIOD:

FROM MAY, 1979 **THROUGH** JANUARY, 1982

PROJECT OBJECTIVES: Design, development and test of a residential application gas-fired heat pump (GHP). The heat pump is targeted for a capacity of 37,300 Btuh cooling or 38,500 Btuh heating. The compact, hermetic system is comprised of two rotating assemblies; a high speed (48,000 RPM) turbomachine core and a low speed (1,200 RPM) assembly which consists of a vapor generator, two condensers, and an evaporator.

PROJECT DESCRIPTION AND STATUS: The GHP differs from conventional heat pumps in several ways. The heat pump is fired by a gas-fired atmospheric combustor. Rotating heat exchangers are used to circulate the conditioned air, and there is no pump in the power cycle or reversing valve in the refrigeration cycle. The GHP is a single package system in a compact housing and changes air flow circuits to convert from a cooling to a heating mode. Also, the GHP uses waste heat recovery to improve its performance in the heating mode.

The GHP uses both a Rankine power cycle and a Rankine refrigeration cycle. The components of these cycles are configured into three basic modules; a power module which drives the system, a condenser module which serves both the power and refrigeration cycles, and an evaporator module which cools and conditions the house air or absorbs heat from the outside air. The condensers and the evaporator never change their respective functions. The change from cooling to heating mode is done via rerouting of the air flow circuits. The path of the power and refrigerant cycle fluids inside the heat pump never changes, and no reversing valve is required. Air enters the heat pump through air ducts, is pumped by and through the rotating heat exchangers, and exits via discharge ducts.

Phase I of this program, which involved the design, procurement, fabrication and component testing along with analysis studies for system performance, cost and market applications, has been completed. The program is now in Phase II in which system performance maps will be completed for the laboratory model. A proposed Phase III effort involves the engineering development of a prototype unit with participation by commercial HVAC vendors.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 37,300 (cooling); 38,500 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Fluid B (power loop); R113 (Rankine loop)/gas/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95 (cooling) ; 47 (heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.70 (cooling) ; 1.34 (heating)

PROJECT SUMMARY

PROJECT TITLE: CHILLER DRIVEN BY A SOLAR STEAM-POWERED RANKINE ENGINE

PRIN. INVESTIGATOR: N. LIOR AND H. YEH

ORGANIZATION: DEPT. OF MECHANICAL ENGRNG.
UNIV. OF PENNSYLVANIA

ADDRESS: 111 TOWNE BLDG/D3
PHILADELPHIA, PA 19104

TELEPHONE NO.: (215) 243-4803

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 678,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: AC03-78ET-20110

CONTRACT AGENCY: DEPARTMENT OF ENERGY SAN FRANCISCO

CONTRACT PERIOD:

FROM November, 1977 **THROUGH** October, 1980

PROJECT OBJECTIVES: Design and development of a 20-ton superheated steam Rankine chiller.

PROJECT DESCRIPTION AND STATUS: The system features include: a solar collection loop to heat water to 260°F; a gas-fired boiler to further superheat to 1100°F; a five-stage, 15,000 rpm radial outflow steam turbine and rotary expander design; the stored water is flashed to steam.

Design of the turbine unit and test loop has been completed and fabrication of the two units is proceeding. Once completed, performance maps of the turbine will be measured using the steam power loop.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	25 ton
WORKING FLUID/HEAT SOURCE/HEAT SINK:	steam (power cycle); freon (compressor)/air/chilled water
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	115/45-54
STEADY-STATE C. O. P. AT DESIGN TEMP.:	0.72-1.2

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF A HIGH TEMPERATURE SOLAR POWERED WATER CHILLER FOR USE IN A SOLAR HEATING AND COOLING SYSTEM

PRIN. INVESTIGATOR: RICHARD A. ENGLISH

ORGANIZATION: ENERGY SYSTEMS DIVISION
CARRIER CORPORATION

ADDRESS: CARRIER TOWER, P.O. BOX 4800
SYRACUSE, NEW YORK 13221

TELEPHONE NO.: (315) 424-4623

SUBCONTRACTOR: (if applicable) MECHANICAL TECHNOLOGY, INC.
968 ALBANY SHAKER ROAD
LATHAM, NEW YORK 12110

MR. EWAN CHOROSZYLOW
(518) 785-2334

TOTAL FUNDING: $1,676,996

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC-3-77CS31590

CONTRACT AGENCY: DOE - SAN FRANCISCO OPERATIONS OFFICE

CONTRACT PERIOD:

FROM OCTOBER 1977 **THROUGH** SEPTEMBER 1981

PROJECT OBJECTIVES: To design, construct, test, and analyze a solar powered Rankine cycle 25 ton air cooled water chiller.

PROJECT DESCRIPTION AND STATUS: The design concept being developed is a dual loop, Rankine power cycle driving a Rankine vapor compression cycle. A single working fluid, R-113, is used and both loops are connected to a common air cooled condenser. The prime mover is a 24,000 rpm turbine directly driving a centrifugal compressor. Under design conditions of 45°F leaving water, 95°F entering condenser air, and 290°F entering solar hot water, the unit is designed to produce 25 tons. The cycle employs a regenerator and a suction gas heat exchanger which act synergistically to increase cycle efficiency. The heat exchange components, working fluid, and turbo compressor configuration were optimized to produce a high overall COP which is predicted to be above 0.70. The auxiliary energy source is a variable speed induction motor which can drive the compressor when solar energy is not available. The turbomachine shaft is supported on hydrodynamic gas bearings to eliminate conventional lubricants from the cycle.

The turbo machine was built by the subcontractor and tested successfully on air. The chiller has been built in a water cooled configuration to facilitate initial turbo machine testing. The turbo machine has been installed and the complete test facility instrumented. Initial spin tests are underway to evaluate the rotor dynamics and bearing performance in the R-113 environment.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	300,000 Btu/hr (cooling)
WORKING FLUID/HEAT SOURCE/HEAT SINK:	R-113/water/air
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	95°/45° (cooling)
STEADY-STATE C. O. P. AT DESIGN TEMP.:	0.745 (cooling)

PROJECT SUMMARY

PROJECT TITLE: Development and Demonstration of a High COP Rankine Heat Pump for Generation of Process Steam Combined Cycle Steam Compression Industrial Heat Pump

PRIN. INVESTIGATOR: Mr. William Koebbeman

ORGANIZATION: Mechanical Technology Inc.

ADDRESS: 968 Albany-Shaker Road
Latham, NY 12110

TELEPHONE NO.: (518) 899-2976

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,922,994

SOURCE(S)	LEVEL (%)
Department of Energy	100%
Mechanical Technology Inc.	2% additional

CONTRACT NO.: DE-AC01-77CS 40074

CONTRACT AGENCY: Department of Energy

CONTRACT PERIOD:

FROM 10/14/77 **THROUGH** 2/14/81

PROJECT OBJECTIVES: To design, develop, install, and field demonstrate a combined cycle heat pump for generation of process steam in an operation plant.

PROJECT DESCRIPTION AND STATUS: Heat pump compressors conventionally are electric motor driven. In this concept, the compressor ("pumping" low pressure steam to process steam levels) is driven by the turbine output of a closed, organic Rankine cycle loop. The heat source both for the Rankine cycle and for generating low pressure steam is the industrial "waste" heat effluence. Elimination of electrical power to drive the compressor provides the economic attractiveness of this heat pump system.

Major emphasis in the development of this system is the turbine. It must be designed optimally for efficiency and cost so that there is a short payback period during the time that "waste" energy is being recovered. Full scale operation will be demonstrated in an industrial chemical plant. Detail design of the system is proceeding.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 18 million Btu/hr.

WORKING FLUID/HEAT SOURCE/HEAT SINK: R11/low temp. steam/water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) $136^{o}/215^{o}$ (ORC)/25 psig, 371°F delivery steam

STEADY-STATE C. O. P. AT DESIGN TEMP.: Not applicable since compressor is mechanically driven - not electric motor driven.

PROJECT SUMMARY

PROJECT TITLE: DESIGN AND FABRICATION OF AN ADVANCED PROTOTYPE SOLAR-POWERED TURBOCOMPRESSOR HEAT PUMP

PRIN. INVESTIGATOR: FRANK R. BIANCARDI (UTRC)
JAMES W. SITLER (HSD)
(SOLERAS PROJECT) G. MELIKIAN (UTRC)

ORGANIZATION: UNITED TECHNOLOGIES RESEARCH CENTER (UTRC) AND HAMILTON STANDARD DIVISION OF UNITED (HSD)

ADDRESS: SILVER LANE
EAST HARTFORD, CONN. 06108

TELEPHONE NO.: (203) 727-7234

SUBCONTRACTED FROM: HAMILTON STANDARD DIVISION OF UNITED TECHNOLOGIES CORP.
WINDSOR LOCKS, CONN.

MR. JAMES W. SITLER

TOTAL FUNDING: $1,672,550 (SOLERAS NOT INCLUDED)*

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

* COOPERATIVE AGREEMENT - UTRC PARTICIPATED IN FUNDING)

CONTRACT NO.: DE-AC03-77CS34510

CONTRACT AGENCY: DOE SAN FRANCISCO OPERATIONS

CONTRACT PERIOD:

FROM SEPTEMBER, 1977 **THROUGH** SEPT. 30, 1982

PROJECT OBJECTIVES: The current objective of this program is to design, fabricate and assemble a MOD-2 heat pump which incorporates design improvements and features identified in the laboratory and field testing of the MOD-1 unit and that could result in higher system performance, reliability, and lower manufacturing cost.

Under a recently completed program phase, the MOD-1 prototype solar-powered turbocompressor heat pump was successfully subjected to 250-hr of extensive laboratory testing to demonstrate its component and overall performance, reliability and endurance characteristics. As part of the SOLERAS solar cooling engineering field test effort, the MOD-1 was modified and used in a complete UTRC solar cooling system in a Hamilton Test Systems, Inc. office building located in Phoenix, AZ.

PROJECT DESCRIPTION AND STATUS: The present project is a continuation of an R&D effort started in 1974 under NSF/ERDA, and later DOE sponsorship expanded in 1977 by DOE (Solar Active Buildings Systems office to include the design, development and test of Rankine-cycle heat pumps powered by solar energy for use in multi-family residential and light commercial buildings.

The UTC heat pump (HP) system, incorporates a Rankine-cycle power loop in which a centrifugal turbine is used to drive a centrifugal compressor in a vapor compression refrigeration loop. The thermal energy to the power loop is provided at temperatures up to 300 F (149 C) by a medium-concentration solar collector array. Auxiliary energy for cooling is provided by a fossil-fuel-fired furnace. Heating can be provided by direct solar, direct furnace, or furnace-driven heat pumping of low-temperature solar energy in combination with power loop heat recovery. The HP is rated at 18 tons for cooling and approximately 500,000 Btu/hr for heating. It utilizes low-maintenance air-cooled condensers for heat rejection and conventional HVAC design heat exchangers and controls. Refrigerant 11, a common fluorocarbon is used as the working fluid in both the power and cooling loops.

The measured COP in the heat pump mode has ranged from 1.4 to 2.5 at output capacities from 200,000 to 550,000 Btu/hr. A COP in cooling of 0.5 to 0.75 at up to 20 tons output has been demonstrated in laboratory and field tests.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 216,000 (cooling); 500,000 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R11/water/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 285 F (R11)/95 F db (air)/44 F chilled water output (cooling)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.7 (cooling); 275 F (R11)/50 F (water)/1.4 (heating)/125 F air

PROJECT SUMMARY

PROJECT TITLE: DEMONSTRATION OF A SOLAR STEAM TURBINE ENGINE FOR HEATING AND COOLING

PRIN. INVESTIGATOR: J. MARTIN

ORGANIZATION: ENERGY TECHNOLOGY, INC.

ADDRESS: 4914 E. 154TH ST.
CLEVELAND, OH 44128

TELEPHONE NO.: (216) 587-0555

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 91,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: DE-AC03-80CS30214 AND DE-AC03-77CS34543

CONTRACT AGENCY: DEPARTMENT OF ENERGY SAN FRANCISCO

CONTRACT PERIOD:

FROM SEPTEMBER, 1977 **THROUGH** NOVEMBER 31, 1980

PROJECT OBJECTIVES: The objective of this program was to design, fabricate and test actual heat source solar Rankine turbine engine for application to commercial air conditioning systems.

This project was carried out under two separate DOE contracts (77CS34543 and 80CS30214); Phase I and Phase II. The Phase I study was to perform the basic engineering design and analysis studies with Phase II to demonstrate system performance. Additional phase programs were planned but canceled due to lack of funds.

PROJECT DESCRIPTION AND STATUS: The solar cooling system consists of three major subsystems: heat source, Rankine engine, and a conventional vapor compression loop. The Rankine engine was designed to supplement the low temperature solar input with a high temperature source from a concentrating collector and a combustion heater. This permits a large reduction in solar collector size; reducing capital cost. The working fluid for the Rankine engine was steam.

The test turbine was designed to produce 31 hoursepower at a design speed of 75,000 RPM to drive a solar cooling system of nominal 30 tons capacity. A solar collector requirement of 55 square feet per ton of cooling was projected, if 20 percent of the annual energy supplied is at 1000°F. The initial turbine design point efficiency estimate was 78 percent.

Tests were conducted at ETI's Steam Turbine Test Facility. A natural gas fired steam generator was used to simulate the solar collector thermal output, and the refrigerant compressor load on the turbine was simulated with a direct driven water pump.

The turbine was tested up to 60,000 RPM at a power output of 24 horsepower. An efficiency of 68 percent was measured at this condition. The testing was discontinued with the rotating unit in good condition due to limitations of contract funding. Extrapolation of the measured data to the design conditions indicated that, at the design speed of 75,000 RPM, a power output of 35 horsepower and an efficiency of at least 75 percent would have been reached.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	30 tons
WORKING FLUID/HEAT SOURCE/HEAT SINK:	steam(power cycle)/heat source and sink must be determined
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	determined by the compressor used
STEADY-STATE C. O. P. AT DESIGN TEMP.:	determined by the compressor used

PROJECT SUMMARY

PROJECT TITLE: CONSOLIDATED NATURAL GAS SERVICE COMPANY HEAT-PUMP INTEGRATED COMMUNITY ENERGY SYSTEMS ASSESSMENT

PRIN. INVESTIGATOR: P. F. SWENSON

ORGANIZATION: CONSOLIDATED NATURAL GAS RESEARCH CENTER

ADDRESS: MECHANICAL TECHNOLOGY INC.
11001 CEDAR AVE.
CLEVELAND, OH 44106

TELEPHONE NO.: (216) 421-6314

SUBCONTRACTOR: (if applicable)

INSTITUTE OF GAS TECHNOLOGY (IGT)

TOTAL FUNDING: $ 180,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	99
CONSOLIDATED NATURAL GAS	1

CONTRACT NO.: 31-109-38-4980

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM SEPTEMBER, 1977 **THROUGH** OCTOBER 1, 1979

PROJECT OBJECTIVES: The objectives of this program are to perform economic and performance analyses of the heat-actuated heat pump centered integrated community energy system (HAHP-ICES) concept to both general and site-specific communities consisting of a mix of residential and commercial buildings located in close proximity to a central utility plant. The analyses are used to assess energy savings, reduction in environmental emissions, factors effecting economic and commercial viability, and expected market impacts as compared to conventional HVAC systems.

PROJECT DESCRIPTION AND STATUS: The HAHP-ICES concept consists of a central plant thermal utility which satisfies the heat, cooling, and domestic hot-water needs for a community of buildings located in close proximity to the central plant. A distribution system of insulated piping physically connects the central plant to the community. The major component of the central plant is a gas-fired steam generator/turbine driven heat pump.

Two communities were used to provide thermal loads for the central plant. The first, a hypothetical community located in a climate similar to Chicago, was used as a base case for utility plant design, and showed that the HAHP-ICES could reduce energy consumption up to 30% with emissions for various pollutants being reduced between 39 and 77%. Economics were favorable provided that: the ratio of heating to cooling requirements were greater than 3:1, the region climate featured a high number of heating days (this factor can be off-set by thermal load selection), and that energy costs and utility rate structures are reasonable.

The site-specific community consisted of 42 townhouses, five 120-unit low-rise apartment buildings, five 104-unit high-rise apartment buildings, one 124,000 ft^2 office building, and a single 135,000 ft^2 retail building located in Monroeville, PA. The analysis for this community indicated energy savings of 15-22% and pollutant reductions of 20-81%. Economic studies showed a favorable rate of return on utility plant investment as compared to conventional HVAC systems (24-32%), but slightly lower than conventional district heating (∿34%). Both energy savings and economics were strongly effected by the number of steam turbines employed in the central plant. Market studies indicate that moderate impact is possible in the 1980-1990 time frame.

This work which is completed is detailed in the report entitled "Heat-Pump-Centered Integrated Community Energy Systems" ANL/CNSU-TM-29.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) not applicable

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SOLAR HEATING AND COOLING SYSTEMS: DEVELOPMENT/PRE-PRODUCTION DESIGN/POWER GENERATION

PRIN. INVESTIGATOR: R. L. BUCHHOLZ, G. MARSHALL, S. SCARBOROUGH

ORGANIZATION: HONEYWELL, INC.

ADDRESS: 1700 WEST HIGHWAY 36
ROSEVILLE, MN 55113

TELEPHONE NO.: (612) 378-4134

SUBCONTRACTOR: *(if applicable)*

TOTAL FUNDING: $ 7,200,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100

CONTRACT NO.: NAS8-32093

CONTRACT AGENCY: NASA

CONTRACT PERIOD:

FROM JULY 6, 1976 **THROUGH** SEPTEMBER 30, 1981

PROJECT OBJECTIVES: Design, develop, install and operationally test solar heating and cooling systems with high performance, low cost, modular application and marketability.

PROJECT DESCRIPTION AND STATUS: As the prime contractor responsible for the solar system design, Honeywell teamed with Barber Nichols of Denver, Colorado, and Lennox Industries of Dallas, Texas, and provided the full range of system and subsystem design, fabrication, installation, maintenance, and evaluation. Solar energy systems delivered were: residential heating (two), residential heating and Rankine-cycle air conditioner (R/C-A/C), cooling (four), multifamily/light commercial heating and R/C-A/C cooling (two), and commercial R/C-A/C cooling (two). Additionally, a 16-KVA R/C power generation module and a high-efficiency, high-temperature R/C-A/C power generation module were delivered. Other major accomplishments included: full qualification of the Lennox collector to the Interim Performance Criteria; development of a residential energy transport module; development of a high-performance, low-cost heat exchanger; development of a low-cost collector support structure and headers; definition and testing of several R/C-A/C improvements; and analysis of R/C power generation.

The program is complete except for some close-out details. All systems have performed well, amassing more than 20 years of total operational time. The preliminary evaluation results of the operational history and data indicate: 1) space-heating systems are technically state of the art; 2) R/C-A/C cooling systems perform as designed, but appear unattractive from an energy/cost standpoint; and 3) advanced development in R/C-A/C systems (hardware, configuration and controls) is essential.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 3-ton cooling (residential); 25-ton cooling (commercial)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R113(power cycle); R12(refrigerant cycle)/solar/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95/50 (cooling)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 2.8 - 5.5 (25-ton heating)

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF RANKINE CYCLE SOLAR DRIVEN HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: J. C. GRAF

ORGANIZATION: GENERAL ELECTRIC COMPANY

ADDRESS: POST OFFICE BOX 8661
PHILADELPHIA, PA 19101

TELEPHONE NO.: (215) 962-5565

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 8,591,800.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	85
GENERAL ELECTRIC	15

CONTRACT NO.: NAS 8-32092

CONTRACT AGENCY: NASA-HUNTSVILLE

CONTRACT PERIOD:

FROM MAY 1, 1976 **THROUGH** JULY 31, 1979

PROJECT OBJECTIVES: The objectives of this program were to design and construct solar heating and cooling systems for the residential/commercial markets. Objectives also included the delivery, installation, and monitoring of prototype systems.

PROJECT DESCRIPTION AND STATUS: This design concept is configured with two separate hermetically sealed loops; a Rankine driven loop, and a conventional heat pump loop. The working fluid for the solar driven Rankine cooling loop is FC88, which is circulated via a feed pump through a vapor generator into the expander. The vapor from the expander is condensed in a air side condenser. Energy for the vapor generator is supplied by a solar supplied thermal storage loop. This loop features GETC-100 evacuated tubular collectors which operate at temperatures up to 320°F. The primary solar collector loop utilizes a 35% mixture of ethylene glycol and water circulated by a pump through a heat exchanger which transfers the energy to a thermal storage loop.

A residential (3-ton) unit and two commercial units (10-ton) have been fabricated and tested. Test results for the 3-ton unit have shown cooling performance to be below those of design goals, with typical values of 31,000 BTU/HR cooling capacity and a seasonal operating COP of 0.59 due primarily to lower than design goal expander efficiency. Tests with the 10-ton units which are slightly different in design and feature an improved expander design agree favorably with, and in some instances, better than design goals.

Based on operating experience and additional studies GE believes that significant improvements in operating COP are possible with projected values of 0.9 as compared to test values of ∿0.7 for the 10-ton units. Market studies indicate that moderate penetration is possible in the late 1980s.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 120,000 (ARI-cooling)

WORKING FLUID/HEAT SOURCE/HEAT SINK: FC88 (cooling); R22 (heating)/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 110/49 (cooling)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.74 (cooling)

PROJECT SUMMARY

PROJECT TITLE:

A High Seasonal Performance Factor Gas Heat Pump For The North Central United States

PRIN. INVESTIGATOR: Paul F. Swenson

ORGANIZATION: Consolidated Natural Gas Service Co.

ADDRESS: 11001 Cedar Avenue, Cleveland, OH 44106

TELEPHONE NO.: (216) 421-6144/6314

SUBCONTRACTOR: (if applicable)

Advanced Mechanical Technology Inc.
Masco Corporation
Mechanical Technology Inc. (Principal Subcontractor)
Phillips Engineering
Scientific Energy Systems Corporation
William E. Hill & Company

TOTAL FUNDING: $ 2,475,004

SOURCE(S)	LEVEL (%)
Consolidated Natural Gas Service Co.	50%
U.S. Department of Energy	50%

CONTRACT NO.: EY-76-C-02-2883 (New No. DE-AC02-76CS20041)

CONTRACT AGENCY: U.S. Department of Energy Consumer Product Division

CONTRACT PERIOD:

FROM February, 1976 **THROUGH** December, 1979

PROJECT OBJECTIVES:

1) Demonstrate the technical feasibility of a steam turbine-driven heat actuated heat pump for small and/or large commercial applications.

2) Identify those market areas where a steam turbine-driven heat actuated heat pump could represent an attractive and competitive product.

3) Identify the parameters under which a business venture could succeed based upon manufacturing and marketing steam turbine-driven heat actuated heat pumps.

PROJECT DESCRIPTION AND STATUS:

The program consisted of these principal elements : (1) Technical Effort, (2) Market Potential Study, (3) Comparative Cost of Ownership Study and (4) System Cost Analysis.

The Technical Effort, initiated ahead of the other program elements, included system specifications, component and system design, component and subsystem bench test, and a full 7½-ton breadboard system demonstration test.

The Market Potential Study, conducted by William E. Hill & Co., indicated that the estimated first-cost premium would result in an unacceptably small market at either the 7½-ton or 100-ton size levels.

In spite of the large first-cost premiums, the 7½-ton HSPF system appeared to offer payback periods of 10 to 15 years and the 100-ton system payback periods of 6 to 12 years, depending on the application and, especially, on local utility rates.

Following a review of the above results, the CNG, DOE and MTI project management team determined that all technical effort should be terminated. The basis for this determination was the very low potential indicated for the HSPF gas heat pump to become the basis for a profitable product line.

Despite the severe cost obstacles posed by the high-performance steam turbine prime mover, it was shown to offer acceptable operating efficiency. The steam prime mover also demonstrated the ability to provide these other desirable operating characteristics : (1) Quiet operation, (2) Long service life, with infrequent scheduled maintenance and (3) Low emissions when fired with natural gas or light oils.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 150,000 Heating; 90,000 Cooling

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-11/Air/Air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 120°F/45°F (Cooling)

STEADY-STATE C. O. P. AT DESIGN TEMP.: .65 (With self-propelled auxiliaries, cooling service)

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF ADVANCED RANKINE/RANKINE SOLAR HEATING AND COOLING SYSTEMS

PRIN. INVESTIGATOR: R. NELSON

ORGANIZATION: AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

ADDRESS: 2525 W. 190th Street
Torrance, CA 90509

TELEPHONE NO.: (213) 321-4372

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 5,000,000.

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: NAS 8-32091

CONTRACT AGENCY: NASA

CONTRACT PERIOD:

FROM 1975 **THROUGH** 1980

PROJECT OBJECTIVES: To develop and demonstrate three sizes of integrated solar heating/cooling systems that would be commercially attractive to the residential/commercial market.

PROJECT DESCRIPTION AND STATUS: Three different capacity systems were built and tested in the laboratory. System sizes (based upon maximum cooling capacity) were 3-ton, 25-ton and 75-ton. The systems were designed to operate either with a flat plate solar collector or with 60 Hertz power driving an electric motor hermetically sealed within the system. The refrigerant, R11, was used in both loops of the system.

The project was terminated in 1980 due to lack of funding without field testing being done.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 3, 25, and 75 ton (cooling)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R11/Solar/Water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95/51 (cooling)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 4.0 (heating); .71 (cooling)

SECTION 8

PROJECTS WITH ABSORPTION OR CHEMICAL CYCLES

(34 PROJECTS)

PROJECT SUMMARY

PROJECT TITLE: DYNAMIC PERFORMANCE TESTING OF PROTOTYPE 3 TON CARRIER ABSORPTION CHILLER

PRIN. INVESTIGATOR: BYARD D. WOOD

ORGANIZATION: ARIZONA STATE UNIVERSITY
COLLEGE OF ENGINEERING AND
APPLIED SCIENCE

ADDRESS: DEPARTMENT OF MECHANICAL ENGINEERING
TEMPE, ARIZONA 85287

TELEPHONE NO.: (602) 965-7298

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 44,501.

SOURCE(S)	LEVEL (%)
DOE San Francisco	100

CONTRACT NO.: DE-AC03-81CS30572

CONTRACT AGENCY: DOE San Francisco Operations Office

CONTRACT PERIOD:

FROM September 30, 1981 **THROUGH** September 30, 1982

PROJECT OBJECTIVES: The goal of this project is to measure the steady state and dynamic performance characteristics of a prototype 3 ton, Carrier, air-cooled absorption chiller for a wide range of generator, evaporator and condensor/absorber temperatures.

PROJECT DESCRIPTION AND STATUS: The ASU Solar Cooling Test Facility shall be modified to enable testing of the Carrier absorption chiller dynamically and in steady state, throughout the desired range of generator, evaporator, and condensor/absorber temperatures. The air and water temperature ranges provided shall be:

- Inlet hot water to the generator: 190° to 260°F
- Cooling air to the condensor and absorber couls: 80° to 110°F
- Chilled water exiting from the evaporator: 42° to 60°F

Operating modes shall include instaneous start up, spin up, instantaneous shut down, and spin down, using a range of "on" times and "off" times such that the on/off cycling performance will be fully determined. The detailed test procedures and specific parameter values to be used shall be submitted to and approved by DOE prior to the start of testing.

Correlations of the performance data shall be made using a regression analysis to determine the temperature and time dependent constants for the various predictor equations to predict chiller capacity and COP.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: METAL HYDRIDE/CHEMICAL HEAT PUMP DEVELOPMENT PROJECT

PRIN. INVESTIGATOR: SAMUEL J. CUNNINHGAM

ORGANIZATION: SOUTHERN CALIFORNIA GAS COMPANY

ADDRESS: BOX 3249, TERMINAL ANNEX
LOS ANGELES, CA 90051

TELEPHONE NO.: (213) 689-2345

SUBCONTRACTOR:
(if applicable)

SOLAR TURBINES INTERNATIONAL
P.O. BOX 80966
SAN DIEGO, CA 92138
DR. DAVID A ROHY (714) 238-5604

BOOZ ALLEN & HAMILTON, INC.
4550 MONTGOMERY AVENUE
BETHESDA, MD 20014
PAUL ACKERMAN (301) 951-2525
(funded entirely by Southern California Gas Company)

TOTAL FUNDING: $ 1,336,581

SOURCE(S)	LEVEL (%)
BROOKHAVEN NATIONAL LABORATORY	66%
SOUTHERN CALIFORNIA GAS COMPANY	28%
SOLAR TURBINES INTERNATIONAL	6%

CONTRACT NO.: 530498-S

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM FEBRUARY 1981 **THROUGH** MARCH 1984

PROJECT OBJECTIVES: The objective of the project is to develop a cost effective metal hydride/chemical heat pump for residential, commercial or industrial applications. The development effort is to be carried out in a three-phase program.

The MHHP is a chemical heat pump containing two hydrides for the storage and/or recovery of thermal energy. It utilizes the heat of reaction of hydrogen with specific metal alloys. The MHHP design can be tailored to provide heating and/or cooling over a wide range of input and ambient temperatures. This system can thus be used with a variety of heat sources including industrial waste heat, solar energy or even a fossil fuel.

PROJECT DESCRIPTION AND STATUS:

At the start of the program in Phase I, the conceptual design will be established followed by a national market survey and characterization to identify the most attractive applications and markets. This will be followed by a first-cut commercial feasibility analysis. Upon the completion of these tasks, an engineering development test unit (EDTU) will be designed for the target market application.

In Phase II, the EDTU will be fabricated, tested, rebuilt as necessary and retested. This will lead to the detailed design of an Engineering Evaluation Test Unit (EETU). Additionally, based on the technical results obtained in this Phase, a more indepth commercial feasibility analysis will be performed. During Phase III, the EETU will be fabricated and tested.

The Southern California Gas Company is currently under contract to proceed with Phase I of the program identified above. Funding for Phase II and II are not yet obligated. The conceptual design has been completed. The market survey has been initiated. Potential applications have been identified and characterized. Competing systems have also been characterized in each potential application. A screening criteria is currently being developed in order to evaluate the MHHP for the potential applications already identified. This will lead to a recommended application(s). Efforts to develop the thermal and mechanical designs, controls systems, and selected hydride materials have also been initiated. This work is of a general nature since to date the specific application has not been selected. Development of detailed designs will begin when the most attractive application is identified.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

Design parameters will be established once the best potential application is identified.

PROJECT SUMMARY

PROJECT TITLE: METAL-HYDRIDE HEAT PUMP TECHNICAL SUPPORT AND DEVELOPMENT PROGRAM

PRIN. INVESTIGATOR: DR. J. MICHAEL CLINCH

ORGANIZATION: ARGONNE NATIONAL LABORATORY (ANL)

ADDRESS: 9700 SOUTH CASS AVENUE
ARGONNE, ILLINOIS 60439

TELEPHONE NO.: (312) 972-7693

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $140,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: AL-10-05-15/ANL 49405

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM OCTOBER 1, 1980 **THROUGH** SEPTEMBER 30, 1982

PROJECT OBJECTIVES: To provide technical assistance to Brookhaven National Laboratory (BNL) in support of the metal hydride heat pump development contract work. To carry out, in support of the project, analytical work to evaluate the performance of a metal hydride heat pump.

PROJECT DESCRIPTION AND STATUS: A metal-hydride heat pump that utilizes the heat of absorption/desorption of hydrogen on a metal alloy surface has been under development. This system can be used with a variety of heat sources, including industrial waste heat, solar energy or fossil fuels. Recent Argonne National Laboratory (ANL) efforts have focused on a multi-tube design for the heat pump which uses many identical sealed tubes, each containing, at opposite tube ends, a high temperature and a low temperature hydride. To minimize performance losses due to thermal cycling, the design employs regenerative heat exchange. Expressions for the coefficient of performance (COP) of the multi-tube hydride heat pump design have been developed for the heating and cooling modes. An examination of system design and operating parameters and determination of the sensitivity of thermal performance to variations in these parameters has been made to identify and seek methods of improving the COP. Limits have also been established on the maximum theoretical Carnot COP of the hydride heat pump. In addition to this in-house analytical work, a commercial firm has been selected by DOE/Brookhaven National Laboratory (BNL) to develop, design and construct a prototype metal hydride heat pump. Argonne National Laboratory has been assisting BNL in reviewing the contractor's technical progress.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

Not applicable

PROJECT SUMMARY

PROJECT TITLE:

STUDY OF THE SIMULTANEOUS HEAT AND MASS TRANSFER
IN ABSORPTION/DESORPTION PROCESSES

PRIN. INVESTIGATOR: Gershon Grossman

ORGANIZATION: Oak Ridge National Laboratory

ADDRESS: P.O. Box Y, Bldg. 9102-2, Room 111
Oak Ridge, Tennessee 37830

TELEPHONE NO.: (615) 574-1083

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 100,000 (Est.)

SOURCE(S)	LEVEL (%)
Department of Energy	100%

CONTRACT NO.: W-7405-eng-26/AA-55-15-15-0

CONTRACT AGENCY: Dept. of Energy

CONTRACT PERIOD:

FROM October 1980 **THROUGH** September 1982

PROJECT OBJECTIVES: To develop fundamental and quantitative information on the combined heat and mass transfer occurring in absorption and desorption.

Basic quantitative understanding of the absorption/desorption processes is needed for the design and scaling of advanced components of absorption equipment. This information, obtainable by means of theoretical analysis supported by experimental data, would yield the heat and mass transfer coefficients in the process and their dependence on the operating conditions and material properties.

PROJECT DESCRIPTION AND STATUS: Absorption and desorption processes occur in many chemical engineering operations. One application of particular interest where these processes take place is in absorption heat pumps and chillers. It was realized quite some time ago that basic information, including theoretical models and experimental data on the simultaneous heat and mass transfer in absorption/desorption, is lacking. The literature describes mass transfer under isothermal conditions, or heat transfer at fixed concentrations. Little information is available on the combination of both. Empirical data on the combined process have been gathered by manufacturers of absorption equipment for selected material combinations under limited operating conditions. These data are not generally available.

Under the present study, it has been planned to develop several theoretical models on the simultaneous heat and mass transfer process in absorption/desorption, and compare their results with experimental data. The first model, recently completed, involves laminar flow and considers the variation in concentration and temperature in a falling film as the process takes place. Results include the heat and mass transfer coefficients and scaling laws of the process. More advanced models will consider rippled and turbulent flows. Boundary layer growth and non-equilibrium effects at the film-vapor interface will be studied.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ADVANCED ABSORPTION HEAT PUMP

PRIN. INVESTIGATOR: F. Bert Cook

ORGANIZATION: Columbia Gas System Service Corp.

ADDRESS: 1600 Dublin Road
Columbus, OH 43215

TELEPHONE NO.: (614) 486-3681

SUBCONTRACTOR: (if applicable)
Battelle Memorial Institute (BCL)
505 King Avenue
Columbus, OH 43201

Thermacore, Inc.
780 Eden Road
Lancaster, PA 17601

TOTAL FUNDING: $ 2,600,000 (Current Phase $1,445,000)

SOURCE(S)	LEVEL (%)
Columbia Gas - $1,800,000	69%
GRI - $ 800,000	31%

CONTRACT NO.: 5080-341-0344

CONTRACT AGENCY: Gas Research Institute

CONTRACT PERIOD:

FROM October 1, 1980 **THROUGH** March 30, 1982

PROJECT OBJECTIVES: The primary objectives of the current program are: design, fabrication and testing of a breadboard heat pump prototype; demonstration of target system performance in the breadboard prototype; and, design of a packaged prototype heat pump. Support studies include evaluation of the thermophysical properties, corrosion potential and toxicity of the solution; design and fabrication of recouperative and interface heat exchangers; design and fabrication of a solution pump and control system; development of a dynamic model of the heat pump system; and, a preliminary assessment of the potential market.

PROJECT DESCRIPTION AND STATUS: The present project is a continuation of a research and development effort carried out initially by Columbia Gas System Service Corporation. The advanced absorption heat pump under design and development is based on a novel refrigeration cycle and absorbent/refrigerant solution.

A static mathematical model of the refrigeration cycle has been developed and was used to assist component design. The model will also be used as the basis for analysis of test data, and for design of advanced components.

The advanced absorption heat pump is in the early stages of development. A breadboard prototype has been fabricated and is currently undergoing preliminary testing. This prototype will be used to assess actual heat transfer in the refrigeration cycle and as a test bed for improved system components.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 (Cooling); 68,000 (Heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Proprietary/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95°/45° (Cooling); 95°/47° (Heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.8 (Cooling); 1.5 (Heating)

PROJECT SUMMARY

PROJECT TITLE: OPEN CYCLE CHEMICAL HEAT PUMP AND ENERGY STORAGE SYSTEMS

PRIN. INVESTIGATOR: HARRY ROBISON

ORGANIZATION: COASTAL CAROLINA COLLEGE/UNIVERSITY OF SOUTH CAROLINA ENERGY LABORATORY

ADDRESS: Conway, SC 29526

TELEPHONE NO.: (803) 347-3161

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 98,488

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: EG-77-C-01-4042

CONTRACT AGENCY:

CONTRACT PERIOD:

FROM JULY 1980 **THROUGH** SEPTEMBER 1981

PROJECT OBJECTIVES: The objective of this project is to speed the development of a marketable solar powered chemical heat pump that is a technically viable, environmentally acceptable, and economically competitive alternative to conventional space heating and cooling methods.

PROJECT DESCRIPTION AND STATUS: Two types of solar regeneration equipment will be tested, (1) trickle-collector, (2) plastic solar collectors with of-the-shelf regenerator. System uses water as refrigerant; has no mechanical compressor, no vacuum or pressure system, no condenser, no gas-fired generator, no large insulated storage. Can be powered by solar, waste heat, or off-peak electricity.

Testing has been completed on the trickle-collector and tests on the plastic collectors are underway.

The contractor built a 2800 sq. ft. house to demonstrate system operation. With a solar fraction of 1.0 the 24 hour performance was COP = 0.6 (refrigeration effect divided by the total incident solar energy).

The system EER was 9.8. By optimizing motor horsepower an improvement is expected.

The system will also operate on low grade waste heat.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 40,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Solar - Well water and common salt solution ($Ca\ Cl_2$)
Open Cycle Liquid Desiccant

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.6 solar COP

PROJECT SUMMARY

PROJECT TITLE: DETERMINATION OF PROPERTIES OF FLUIDS FOR SOLAR COOLING APPLICATIONS

PRIN. INVESTIGATOR: R. THOMAS PODOLL

ORGANIZATION: SRI INTERNATIONAL

ADDRESS: 333 Ravenswood Avenue
Menlo Park, CA 94025

TELEPHONE NO.: (415) 859-5834

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 121,857

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-80CS 30221

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1980 **THROUGH** JANUARY 1982

PROJECT OBJECTIVES: The objectives of this project are to determine pressure-volume-temperature (P-V-T) data and calorimetric data for organic refrigerant and absorbent fluids and their binary mixtures that are accurate enough to be used for the design of solar-powered cooling engines.

PROJECT DESCRIPTION AND STATUS: Determine P-V-T data and calorimetric data for organic refrigerant and absorbent fluids and their binary mixtures. Fluids tested: Refrigerants - ammonia, methylamine, ethylamine, dichlorofluoromethane, difluorochloromethane absorbents-Ethylene glycol; 1, 4-butanediol; diethylene glycol dimethyl ether; N, N-dimethylacetamide; N, N-dimethyldecanamide.

Note: A 4-month time extension has been requested.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Various (see project description above)

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: CHEMICAL HEAT PUMP COST-EFFECTIVENESS EVALUATION

PRIN. INVESTIGATOR: WARREN R. STANDLEY

ORGANIZATION: TRW ENERGY ENGINEERING DIVISION

ADDRESS: 8301 GREENSBORO DRIVE
MCLEAN, VIRGINIA 22102

TELEPHONE NO.: (703) 734-6534

SUBCONTRACTOR: (if applicable) N/A

TOTAL FUNDING: $ 98,346

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 519403-S

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM JUNE 1980 **THROUGH** MARCH 1981

PROJECT OBJECTIVES: The objective of this study was to compare the cost effectiveness and energy effectiveness of existing chemical heat pump (CHP) concepts with a baseline of conventional energy technologies and a group of near-term emerging energy technologies with which CHPs are expected to compete. The analysis was structured to evaluate these systems functioning as the primary space conditioning unit of both a "standard" single-family detached home and a "representative" commercial building. Each HVAC system and application was analyzed in each of two locations in the United States, the southwest (Albuquerque, NM) and the northeast (Boston, MA). In addition, the CHPs were evaluated in two "representative" industrial waste heat upgrading applications, and compared to potentially-competitive technologies for industrial "heat pumping."

PROJECT DESCRIPTION AND STATUS: The Energy Engineering Division of TRW has conducted a comparative economic and energy consumption evaluation of chemical heat pumps (CHPs) in support of the Chemical/Hydrogen Energy Storage Systems Program at Brookhaven National Laboratory (BNL). CHPs extract thermal energy from a low-temperature source and reject it to a higher-temperature sink. Unlike vapor-compression heat pumps, chemical heat pumps make use of reversible chemical reactions between a working fluid (or vapor) and one or more stationary phases (solid or liquid). Chemical heat pumps are being developed by DOE and BNL because they offer the promise of lower overall cost and greater efficiency than separate units for heating, cooling, and (in solar operations) storage. They are also being considered for industrial process heat upgrading applications. In these roles, CHPs must compete successfully on economic levels with present-day baseline systems and with near-term emerging technologies. The study described in this paper addresses both aspects of the comparison, that is, the cost effectiveness and energy resource effectiveness of CHPs.

Under contract to Brookhaven National Laboratory, TRW conducted a cost-effectiveness and energy resource evaluation of two chemical heat pump (CHP) concepts: a sulfuric acid-water CHP and a methanol-calcium chloride CHP. The CHPs were compared to baseline and emerging competitive technologies for providing space conditioning services to residential and commercial buildings and for upgrading industrial process heat, using levelized annual cost as the measure of cost effectiveness. The study concluded that CHPs could be cost effective and conserve energy resources in applications for industrial process heat upgrading and, in specific applications, for residential heating and cooling. CHPs for commercial office building space conditioning are neither resource nor cost effectiveness.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: COMPOUND ABSORPTION COOLING FROM LOW-GRADE HEAT USING ADVANCED DESORBERS

PRIN. INVESTIGATOR: DR. WILLIAM T. HANNA & William H. Wilkinson

ORGANIZATION: BATTELLE COLUMBUS LABORATORIES

ADDRESS: 505 KING AVENUE COLUMBUS, OHIO 43201

TELEPHONE NO.: (614) 424-4794

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 428,765

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: W-7405-eng-26 Subcontract No. 7805

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM FEBRUARY, 1980 **THROUGH** OCTOBER, 1981

PROJECT OBJECTIVES: The overall objective of this program is to demonstrate the commercial feasibility of an advanced absorption cooling system known as the Compound Absorption Chiller (CAC) which is motivated by low-grade heat. The program is organized into four phases having the following specific objectives. In the First Phase (Feasibility Study) the phase objectives were to show preliminary indications of technical and economic feasibility in recommended applications and to provide analytical performance estimates for a demonstration unit. In the Second Phase (Engineering Analysis and Design) the specific objectives were to: design experimental equipment, and establish a design basis for an advanced desorber to be scaled up for use in the cooling system. The objective in the Third Phase (Experimental Study) was to conduct bench scale experiments on conventional and advanced desorber designs to determine heat transfer coefficients and other design information. In the current, Fourth Phase (Testing) the objective is to construct and test a nominal 25 ton capacity chiller, motivated by low-grade heat, to verify the performance predictions of the analytical model.

PROJECT DESCRIPTION AND STATUS: The project is organized into four Phases and the technical accomplishments are discussed for each phase. In the First (Feasibility) Phase, the major results were the development of a detailed computer performance model for the CAC system and the use of that model, with absorption equipment cost data to predict the relative cost and benefits of using CAC systems. The results of the Second (Engineering Analysis) Phase were: the definition of three desorber designs and an experimental plan for ranking them, and the design of a heat exchanger using the best of these designs for incorporation into the later test unit. In the Third (Experimental) Phase, the desorber tests, planned in Phase II, were carried out for one pool type and two advanced desorbers; with the result that one of the advanced desorbers, a counterflow unit, gave improved heat transfer (by 1400%) and improved costs (by 140%) as compared to a pool desorber. In the current Phase IV Test Effort, the CAC demonstration unit has undergone detailed design and construction is nearing completion on a 25 to 50 TR waste heat driven, 140 F input chiller. Testing is scheduled for 2 months beginning in June. Post-contract activities include plans for commercialization via a licensed manufacturer and operation of the CAC demonstration unit in an industrial type application.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 0.3×10^6 (25 Tons of Refrigeration)
Commercial Product Capacity Range (100TR to 1500TR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Lithium Bromide and Water/Waste Heat/Cooling Water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 85 F/35 F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.42

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT AND DEMONSTRATION OF AN AMMONIA-WATER ABSORPTION HEAT PUMP

PRIN. INVESTIGATOR: RICHARD H. MERRICK

ORGANIZATION: ARKLA INDUSTRIES INC.

ADDRESS: P. O. BOX 534
EVANSVILLE, IN 47704

TELEPHONE NO.: (812) 424-3331

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,052,772

SOURCE(S)	LEVEL (%)
DOE	95%
ARKLA	5%

CONTRACT NO.: 86X-61603C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM JANUARY 1980 **THROUGH** MAY 1983

PROJECT OBJECTIVES: The objective is to develop a residential air-source ammonia-water absorption heat pump designed to operate in the heating mode only and deliver its output as hot water.

PROJECT DESCRIPTION AND STATUS: This project is based on applying the virtues of ammonia-water absorption, proven in cooling, to heating. The cycle will be used non-reversing. Integrating electric compression cooling into the product will be considered too. The product is targeted for northern climates.

A prototype unit has been developed and three life test and three field test units will be operating during the '81/'82 winter. Prototype specifications are 50,000 Btuh input, 125F supply water, 105F return water, COP 1.25 @ 47F ambient and 1.12 @ 17F ambient.

Developing an advance prototype unit with some performance and cost saving enhancements is to follow.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 60,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Ammonia-water/air/water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 105°/17°

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.2

PROJECT SUMMARY

PROJECT TITLE: FIELD TEST OF SMALL COMMERCIAL BUILDING WATER COOLED SOLAR ABSORPTION CHILLER

PRIN. INVESTIGATOR: WENDELL BIERMANN

ORGANIZATION: CARRIER CORP
ESD

ADDRESS: CARRIER TOWER, P.O. Box 4800
SYRACUSE, NEW YORK 13221

TELEPHONE NO.: (315) 424-4626

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 285,000

SOURCE(S)	LEVEL (%)
SOLERAS	100

CONTRACT NO.: DE-FC02-80-ET (20643)

CONTRACT AGENCY: SERI/SOLERAS

CONTRACT PERIOD:

FROM OCTOBER, 1979 **THROUGH** NOVEMBER 1982

PROJECT OBJECTIVES: The long term objective of the program which has been implemented by the contract enumerated above was the development of a broad line of absorption chillers designed to operate with hot fluids at as low a temperature as practical while rejecting heat to a stream of water.

A second objective was to develop a packaging concept for solar application in which controls, pumps, valves and other system components could be factory assembled into a unitary solar module.

PROJECT DESCRIPTION AND STATUS: Develop improved designs (over Tyler and Big Eddy). Install, using tracking concentrating trough collectors at the BDP Distribution Center, Phoenix, Arizona.

Project has been completed effective January 1982. Monitoring of system operation is considered during FY82.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 180,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Solar 180°F to 220°F/cooling tower

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 85/45

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.72

PROJECT SUMMARY

PROJECT TITLE: SOLERAS TEST AND DEVELOPMENT OF AIR COOLED ABSORPTION CHILLERS FOR SOLAR COOLING APPLICATIONS

PRIN. INVESTIGATOR: WENDELL BIERMANN

ORGANIZATION: CARRIER CORP.
ESD

ADDRESS: Carrier Tower
P. O. Box 4800
Syracuse, NY 13221

TELEPHONE NO.: (315) 424-4626

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 530,000

SOURCE(S)	LEVEL (%)
SOLERAS PROGRAM	100

CONTRACT NO.: DE-FC02-80-ET 20643

CONTRACT AGENCY: SOLERAS/SERI

CONTRACT PERIOD:

FROM October 1979 **THROUGH** NOVEMBER 1982

PROJECT OBJECTIVES: The purpose of this program is to identify the chemical composition of a "best" absorption-refrigerant system, capable of being air cooled to determine those properties of the system necessary to design hot water operated, air cooled chilling equipment and to design and operate air cooled chillers from single family residential sizes into the commercial rooftop size range.

PROJECT DESCRIPTION AND STATUS: Rooftop solar package. Program administered by Solar Energy Research Institute (SERI) under contract DE-FC02-80-ET 20643. Installation Siegler-Fagin Distribution Center, Phoenix, Arizona.

Construction is completed effective Fall, 1981.

Effective Spring, 1982, debugging, adjustments and field modifications are scheduled.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 120,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Lithium Bromide and Ethylene Glycol/water/230°F solar water/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95/45

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.74

PROJECT SUMMARY

PROJECT TITLE: LOW-GRADE-HEAT-ACTUATED ABSORPTION HEAT PUMP FOR TEMPERATURE BOOSTING

PRIN. INVESTIGATOR: Gershon Grossman and Horacio Perez-Blanco

ORGANIZATION: Oak Ridge National Laboratory

ADDRESS: Bldg. 9102-2, Room 111
P.O. Box Y
Oak Ridge, Tennessee 37830

TELEPHONE NO.: (615) 574-1083

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 948,000

SOURCE(S)	LEVEL (%)
Department of Energy	100%

CONTRACT NO.: W-7405-eng-26/AA-55-15-15-0

CONTRACT AGENCY: Dept. of Energy

CONTRACT PERIOD:

FROM October 1979 **THROUGH** September 1982

PROJECT OBJECTIVES: The objective of this project has been to develop a conceptual design of an industrial-type absorption heat pump for upgrading waste heat. The heat pump is designed to boost the temperature of the low-grade heat, typically from about 60°C (140°F) to about 120°C (250°F). The conceptual design forms the first step toward the construction of a laboratory working system. The ultimate goal is to build an industrial scale system.

PROJECT DESCRIPTION AND STATUS: The present study has resulted in a conceptual design of the heat pump system providing the information needed for the detailed design and construction of a laboratory working system. The basic cycle was studied for use with low temperature waste heat (60°C). Multistaging of the heat pump was investigated for increased temperature boosting and a preferred two-stage configuration was identified. Open cycle evaporation and desorption was considered for cases of low temperature differential between the heat source and sink. Suitable working materials were considered and components performance was analyzed at the conceptual design level. The overall system performance was studied for varying operating conditions. Several improvements in the cycle were considered.

A complete computer model of the system was developed to perform the above study. The code is available for investigation of different configurations and operating conditions, and will be used in the detailed design of the laboratory system.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) to be determined

WORKING FLUID/HEAT SOURCE/HEAT SINK: LiBr-water or LiCl-water/water/water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 68°F/140°F

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.38

PROJECT SUMMARY

PROJECT TITLE: SULFURIC ACID/WATER CHEMICAL HEAT PUMP

PRIN. INVESTIGATOR: E.C. CLARK

ORGANIZATION: ROCKET RESEARCH COMPANY

ADDRESS: YORK CENTER
REDMOND, WA 98052

TELEPHONE NO.: (206) 885-5000

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 699,740

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 494588-S

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM OCTOBER 1979 **THROUGH** SEPTEMBER 1981

PROJECT OBJECTIVES: The project is structured to verify the capability of the sulfuric acid-water system. The primary objective is to design, construct, and test a sulfuric acid CHP/CES verification test unit (VTU) which incorporates as many commercial, mass producible design features as necessary to demonstrate system economic and technical feasibility. The VTU will be designed to function both as a storage HVAC unit and a temperature enhancement industrial heat pump. For purposes of gaining scaling criteria, the nominal storage design capacity shall be 10^6 Btu with a nominal delivered heat rate of 150,000 Btu/hr.

PROJECT DESCRIPTION AND STATUS: Rocket Research is currently under contract to Brookhaven National Laboratory to conduct a four-phase program. Phases I, II, and III have been completed and consisted of a requirement analysis, detailed design, and fabrication of the VTU. Generic applications have been identified which include industrial waste heat pumping, space conditioning, air or gas moisture removal, steam accumulation, cogeneration and energy storage. The VTU design incorporates two of the above designs; waste heat pumping and space conditioning. The design incorporates combined generator/condenser and absorber/evaporator reaction components made of steel shells coated with acid-resistant porcelain. Teflon-lined acid plumbing and valves have been used, and the acid storage tank is fabricated from steel lined with porcelain and capable of vacuum operation. The remaining Phase IV test program has been initiated and is currently in progress.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 225,000 Btu/hr (heating); 105,000 (cooling)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Sulfuric acid and water/variable heat sink

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 40-130°F/40-250°F for ICHP

STEADY-STATE C. O. P. AT DESIGN TEMP.: HVAC unit: 1.5 heating/0.7 (cooling); COP_e (ICHP); 10-50

PROJECT SUMMARY

PROJECT TITLE: ORGANIC ABSORPTION GAS-FIRED RESIDENTIAL HEAT PUMP

PRIN. INVESTIGATOR: KEVIN P. MURPHY

ORGANIZATION: ALLIED CORPORATION

ADDRESS: POST OFFICE BOX 1087R
MORRISTOWN, NJ 07960

TELEPHONE NO.: (201) 455-2064

SUBCONTRACTOR: (if applicable)

PHILLIPS ENGINEERING COMPANY
721 PLEASANT STREET
ST. JOSEPH, MICHIGAN 49085
DR. BEN PHILLIPS
(616) 983-3935

ARTHUR D. LITTLE, INC.
CAMBRIDGE, MASS. 02140
MR. E. SHOREY
MR. D. LEE
(617) 864-5770

UNITED TECHNOLOGIES RESEARCH CENTER
EAST HARTFORD, CONNECTICUT 06108
MR. GORKEN MELIKIAN
(203) 727-7554

TOTAL FUNDING: $ 2,300,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	60%
GAS RESEARCH INSTITUTE	40%
ALLIED CORPORATION	17% Additional

CONTRACT NO.: 86X-24610C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM OCTOBER, 1979 **THROUGH** MAY, 1981

PROJECT OBJECTIVES:

The current objectives of this program are to develop an organic absorption gas-fired residential heat pump system to a production prototype level, analyze the market and business potential for the absorption heat pump market, evaluate the system first cost and actual annual performance and operation costs, develop computer simulation of the absorption system to more efficiently examine design variables, develop data for toxicity and product safety, and to identify problems (operate some test units in actual service).

PROJECT DESCRIPTION AND STATUS:

The present project is a continuation of an R&D effort carried out initially under the sponsorship of the American Gas Association and more recently by the Gas Research Institute and the Department of Energy.

The gas-fired absorption cycle heat pump under design and development in this project is based on a novel organic absorption fluid pair. The absorber fluid is ethyltetrahydrofurfurylether (ETFE), and the refrigerant is chlorotrifluorethane (R-133a). The system is characterized by higher capacity and COP in the heating mode than in the cooling mode. Thus, the heat pump system using this fluid combination is more applicable to the northern climates. These organic fluids are compatible with aluminum, and thus will offer a potential fabrication cost advantage over conventional amonia-water absorption equipment.

In the heat pump hardware development, target performance specifications were reached for several key components, including the generator, evaporator and condenser. The regenerative turbine-type solution pump exceeded 30,000 hours of continuous operation and over 200,000 on-off cycles without failure. The overall systems performance has reached over 95% of the target heating efficiency and over 84% of the target cooling efficiency. Full heating and cooling capacities have been demonstrated.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 (cooling); 90,000 (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: R-133a/ETFE/air/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) $95^{o}/47^{o}$ (cooling); $/47^{o}$ (heating)

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.5 (cooling); 1.25 (heating) - Advanced Systems 0.6, 1.50

PROJECT SUMMARY

PROJECT TITLE: ANALYSIS OF LIQUID PHASE HEAT PUMP SYSTEM

PRIN. INVESTIGATOR: KIRK COLLIER

ORGANIZATION: SERI

ADDRESS: 1617 COLE BOULEVARD
GOLDEN, CO 80401

TELEPHONE NO.: (303) 231-1761

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 25,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC02-77CH-00178

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM OCTOBER 1979 **THROUGH** SEPTEMBER 1980

PROJECT OBJECTIVES: To investigate the use of liquid desiccants in heat pump applications.

PROJECT DESCRIPTION AND STATUS: Overall prospects for the use of open-cycle desiccant and absorption systems appear promising. However, there are unanswered questions pertaining to year-round use of the systems. These involve unknown performance-climate relations, and the potential of using the systems for both heating and cooling. SERI is exploring the possibility of combining an open-cycle absorption chiller with a solar-assisted heat pump for summer cooling and winter heating. For this task, the thermal effectiveness of open-flow collectors (the salt-solution working fluid flows over the collector in direct contact with the atmosphere) is being analyzed. If the salt solutions (LiCl and $CaCl_2$) do not freeze or lose water in the winter, the same collectors which evaporate refrigerant to the atmosphere in the summer can be used to supply energy to a vapor-compression heat pump for winter heating. The vapor-compression heat pump is normally needed for back-up cooling in any case. Computer models of the refrigeration system for the cooling season are being adapted to winter conditions for candidate cities. Results of the simulation will determine which operating modes are possible, i.e., as direct heat in absorption heating or as a heat source for a conventional heat pump. In addition, potential problems with freezing/crystallization will be assessed.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: OPEN CYCLE LITHIUM CHLORIDE SOLAR COOLING

PRIN. INVESTIGATOR: GEORGE LOF AND TERRY LENZ

ORGANIZATION: COLORADO STATE UNIVERSITY

ADDRESS: SOLAR ENERGY APPLICATIONS LAB
SOLAR HOUSE I
COLORADO STATE UNIVERSITY
FORT COLLINS, CO 80522

TELEPHONE NO.: (303) 491-8632

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 31,993

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-79CS 30206

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM SEPTEMBER 1979 **THROUGH** MAY 1981

PROJECT OBJECTIVES: The objective of the investigation is the experimental determination of evaporation rates and the coefficients of heat transfer and mass transfer in a packed column designed for use in an open cycle lithium chloride absorption cooling system operated by solar heated air.

Data have been aquired and a final report entitled "Open Cycle Lithium Chloride (Solar) Cooling" was submitted to DOE in December 1981. The data confirm predictions of performance of a small packed column in reconcentrating lithium chloride solutions with heated air.

Further work on this cooling system was initiated in September, 1981, as Task 6 under a multi-task Contract No. DE-AC03-81-CS-30569. A budget of $50,000 is allocated to an investigation of vacuum pumping methods and requirements

PROJECT DESCRIPTION AND STATUS: Investigation of evaporation rates and coefficients of heat transfer and mass transfer in a packed column through which LiCl solution trickle and is reconcentrated by solar heated air.

Data have been aquired and a final report entitled "Open Cycle Lithium Chloride (Solar) Cooling" was submitted to DOE in December 1981. The data confirm predictions of performance of a small packed column in reconcentrating lithium chloride solutions with heated air.

Further work on this cooling system was initiated in September, 1981, as Task 6 under a multi-task Contract No. DE-AC03-81-CS-30569. A budget of $50,000 is allocated to an investigation of vacuum pumping methods and requirements in the lithium chloride-water absorption cooling unit and the design of a complete solar cooling system. This work is scheduled for completion in February 1982.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Solar. Lithium Chloride. Open Cycle.

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) Hot air supply design temp. about 175°F, design evap. temp about 45°F

STEADY-STATE C. O. P. AT DESIGN TEMP.: $\frac{\text{cooling delivered}}{\text{heat to reconcentrator}} = 0.6$

PROJECT SUMMARY

PROJECT TITLE: MULTIPLE-EFFECT ABSORPTION CYCLE SOLAR COOLING

PRIN. INVESTIGATOR: GARY C. VLIET

ORGANIZATION: THE UNIVERSITY OF TEXAS AT AUSTIN: CENTER FOR ENERGY STUDIES/DEPARTMENT OF MECHANICAL ENGINEERING

ADDRESS: AUSTIN, TEXAS 78712

TELEPHONE NO.: (512) 471-7571

SUBCONTRACTOR: NONE
(if applicable)

TOTAL FUNDING: $ 51,032

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY (SAN)	100%

CONTRACT NO.: DE AC03-79SF10540

CONTRACT AGENCY: DOE (SAN)

CONTRACT PERIOD:

FROM September 1, 1979 **THROUGH** November 30, 1980

PROJECT OBJECTIVES: The purposes of this investigation were: to develop a dynamic computer model of the water-lithium bromide double-effect absorption cooling cycle; to use the code to assess the effect on performance of variations in the cycle's several design and operating parameters; and to briefly assess the cost of double-effect absorption cooling per unit of capacity for varying capacity. The work accomplished under this contract has been documented in a contract final report.

PROJECT DESCRIPTION AND STATUS: The absorption cycle is one of the alternatives for solar cooling, and the double-effect absorption cycle is a competitor to proposed Rankine cycle solar cooling systems. While the Rankine cycle has the specific advantage of mechanical/electrical output, the double-effect absorption cycle appears to have a potentially better COP when operating purely in the cooling mode. The double-effect cycle has been available for several years, although there has not been significant interest in it for application to solar cooling systems.

The contract has been completed and a final report submitted to DOE. It included the development of a dynamic computer model to simulate the performance of a water-lithium bromide double-effect absorption cooling system. The code was used to investigate the effect on cycle performance of the several design and operational variables for the cycle. Some project cost data on intermediate capacity units were also made.

Some specific conclusions about optimal system design evolve from these results. The method of refrigerant flow control is important in maintaining high performance over a wide range of source temperatures. This capability is particularly important for a solar-driven system, where the source temperatures will vary considerably. The solution pump characteristic is important, particularly at high source temperatures, with one approaching constant displacement preferred. The relative allocation of heat exchanger area to the cycle's seven heat exchangers is very important to cycle performance and cost, since a large portion of the cost of absorption systems is in heat exchange surface.

A secondary objective of the study was to assess the cost of absorption cycle cooling per unit of design capacity. It would appear that there is merit in considering intermediate capacity double-effect systems in the range of 20 to 100 tons. Since the increased capital costs of the double-effect units (over single) are probably considerably less than the incremental collector cost for solar systems or life-cycle fuel costs for conventional systems, it would appear that the double-effect cycle is a viable choice.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: THERMAL STORAGE STUDIES FOR SOLAR HEATING AND COOLING APPLICATIONS USING SALT CHEMICAL HEAT PUMPS

PRIN. INVESTIGATOR: P. O'D. OFFENHARTZ

ORGANIZATION: EIC CORPORATION

ADDRESS: 55 CHAPEL STREET
NEWTON, MA 02158

TELEPHONE NO.: (617) 965-2710

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 26,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC02-79CS30248

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1979 **THROUGH** APRIL 1980

PROJECT OBJECTIVES: To evaluate the simulated performance of liquid-phase chemical heat pumps in solar heating and cooling applications.

PROJECT DESCRIPTION AND STATUS: Chemical heat pumps are absorption-cycle thermally-activated heat pumps with the inherent capability of chemical storage of thermal energy. Under DOE sponsorship, work is in progress on three different cycles: H_2SO_4/H_2O; NH_4NO_3/NH_3; and $CaCl_2/Ch_3OH$. The first two are based on liquid-gas reactions, and the last on a solid-gas reaction. This difference has required the development of two separate simulation packages. All three chemical heat pumps should be capable of operating under fairly extreme conditions. Absorber-evaporator temperature differences as great as 55°C (130°F) should be achievable. This is technically and economically important because it permits forced air (dry) heat rejection even in desert climates; domestic hot water preheat from the absorber, providing "free" DHW in summer; and system operation in the heating mode even on cold days, using either solar input or fossil (or wood) heat. This helps reduce collector area and expense, and conserves fuel even in the backup mode.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: CHEMICAL/HYDROGEN ENERGY STORAGE SYSTEM: CHEMICAL HEAT PUMP PROGRAM

PRIN. INVESTIGATOR: ALLESSIO MEZZINA

ORGANIZATION: BROOKHAVEN NATIONAL LAB.

ADDRESS: UPTON, LONG ISLAND, NEW YORK 11973

TELEPHONE NO.: (516) 282-3920

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 600,000*

SOURCE(S)	LEVEL (%)
DOE	100

*project management only; excludes subcontract amounts

CONTRACT NO.: DE-AC02-76CH0016

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 1979 **THROUGH** continuing

PROJECT OBJECTIVES: A brief overview of the Chemical Heat Pump Program is presented as a forerunner to more detailed project and systems descriptions which will follow. Program background, rationale, technology description, and research and development needs are addressed. Chemical heat pumps comprise reversible reactions which can be driven by low-grade heat. Thermal energy is absorbed in one direction and liberated in the reverse direction; thus, serving as a basis for system designs applicable to space conditioning or process heat management and offering the capability for high-density energy storage as an integral part of the system.

PROJECT DESCRIPTION AND STATUS: Technical management and support to DOE Chemical Heat Pump Program. Current projects include: 1) sulfuric acid/water CHP at Rocket Research Corp., 2) calcium chloride/methanol CHP at EIC, 3) paired metal hydrides at Southern Cal. Gas/Solar Turbines Intl. Previous projects included: 1) magnesium chloride/water at Chemical Energy Specialists, Inc., 2) ammoniated salts at Martin Marietta Corp., and 3) paired metal hydrides at Argonne Natl. Lab.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: OPERATION AND MAINTENANCE OF SOLAR ENERGY COOLING SYSTEM

PRIN. INVESTIGATOR: J. FRISSORA

ORGANIZATION: SUNMASTER CORPORATION

ADDRESS: 12 SPRUCE STREET
CORNING, NY 14830

TELEPHONE NO.: (607) 937-5441

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 958,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DEN8-000005

CONTRACT AGENCY: NASA

CONTRACT PERIOD:

FROM JANUARY 1979 **THROUGH** SEPTEMBER 1980

PROJECT OBJECTIVES: To manage the operational test phase of the large industrial-scale solar energy cooling system installed at the Holiday Inn on Frenchman's Reef, a large Caribbean resort hotel.

PROJECT DESCRIPTION AND STATUS: Sunmaster has the responsibility for the operation and maintenance of the solar energy collection system which provides heated water to the 200-ton absorption chiller.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: TESTING OF RESIDENTIAL SOLAR CHILLERS

PRIN. INVESTIGATOR: Paul Auh

ORGANIZATION: BROOKHAVEN NATIONAL LAB.

ADDRESS: UPTON, NY
11973

TELEPHONE NO.: (516) 282 -7726

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 50,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC02-76 CH 00016

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM OCTOBER 1978 **THROUGH** SEPTEMBER 1979

PROJECT OBJECTIVES: To evaluate the performance of advanced cooling devices under various realistic operating conditions through the use of hardware simulators.

PROJECT DESCRIPTION AND STATUS: Develop hardware simulators for tests of solar cooling/heating subsystems and systems.

The simulator is capable of performing tests at steady state, transient, dynamic and part or full load conditions.

Steady state results were reported in BNL 51120, "Development of Hardware Simulators for Tests of Solar Cooling/Heating Subsystems and Systems: Phase I. Residential Subsystem Hardware Simulator and Steady State Simulation".

Transient results were reported in BNL 51121, "Development of Hardware Simulators for Tests of Solar Cooling/Heating Subsystems and Systems: Phase II. Unsteady State Hardware Simulation of Residential Absorption Chiller."

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: THERMAL STORAGE FOR SOLAR COOLING USING PAIRED AMMONIATED SALT REACTIONS

PRIN. INVESTIGATOR: F. JAEGER, E. FOX

ORGANIZATION: MARTIN MARIETTA AEROSPACE

ADDRESS: AEROSPACE DIVISION
P.O. BOX 179
DENVER, CO 80201

TELEPHONE NO.: (303) 973-4804

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 428,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC02-78CS-34700

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM JULY 1978 **THROUGH** SEPTEMBER 1980

PROJECT OBJECTIVES: To design, construct, and test a reversible thermochemical heat and storage system.

PROJECT DESCRIPTION AND STATUS: The experimental system is similar in operation to an absorption refrigerator except this unit contains sufficient absorber to be used for thermal storage and operates in the batch mode rather than continuously. The unit consists of two high-temperature reactors, ammonia condensor, ammonia storage tank, expansion valve, evaporator, and heat exchangers. Specific tasks of this project are to:

- Demonstrate concept feasibility using subscale system testing;
- Measure compatibility of appropriate construction materials with candidate ammoniates;
- Select the optimum combination of ammoniates for a residential heating and cooling system;
- Investigate system practicality by conceptual design and cost estimates of a residential unit; and
- Demonstrate system performance by testing a full-scale unit.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: $Mg\ Cl_2 \cdot 6\ NH_3$, $Ca\ Cl_2\ 4\ NH_3$

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DISSOCIATION PRESSURE MEASUREMENTS ON SALTS PROPOSED FOR THERMOCHEMICAL ENERGY STORAGE AND CHEMICAL HEAT PUMPS

PRIN. INVESTIGATOR: ROBERT W. CARLING

ORGANIZATION: SANDIA LABORATORIES

ADDRESS: EXPLORATORY CHEMISTRY DIVISION
LIVERMORE, CA. 94550

TELEPHONE NO.: (415) 422-2206

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ not available

SOURCE(S) **LEVEL (%)**

CONTRACT NO.: DE-AC04-76DP00789

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM 1978 **THROUGH** July, 1979

PROJECT OBJECTIVES: The efficient operation of a chemical heat pump depends strongly upon the reaction energies and pressure/temperature relationships of the salts used. Unfortunately, most of the needed data are not available, old or of uncertain reliability. Therefore, an apparatus has been assembled to measure these data. Incorporated in this apparatus is a sensitive cantilever balance used to prepare salt samples in situ so that stoichiometry of the salt hydrate, ammoniate, or methanolate is known prior to pressure measurements.

PROJECT DESCRIPTION AND STATUS: Pressure/temperature data were obtained over large temperature (293 to 523 K) and pressure (10^{-3} to 10^{5} torr) ranges. The entire experiment was controlled and data were recorded using a desk-top calculator.

Dissociation pressure measurements were made on the $MgCl_2/H_2O$ and $CaCl_2/NH_3$ systems. For the first time on any hydrate system, a complete second- and third-law analysis were done on $MgCl_2 \cdot 6H_2O$ and $MgCl_2 \cdot 4H_2O$. This was made possible by generating free energy functions from available heat capacity data for $MgCl_2 \cdot 6H_2O$, $MgCl_2 \cdot 4H_2O$, and $MgCl_2 \cdot 2H_2O$. Results for $MgCl_2 \cdot 6H_2O$ yielded enthalpies of dissociation at 298.15 K of 27.86 $\pm$ 0.11 and 28.00 $\pm$ 0.03 kcal mol^{-1} H_2O for second- and third-law, respectively. For $MgCl_2 \cdot 4H_2O$, the values determined were 31.7 $\pm$ 0.6 and 32.0 $\pm$ 0.2 kcal mol^{-1} H_2O. These values show excellent internal consistencies (second- and third-law agreement) and external agreement with dissociation enthalpies of 27.82 and 32.42 kcal mol^{-1} H_2O for $MgCl_2 \cdot 6H_2O$ and $MgCl_2 \cdot 4H_2O$, respectively, obtained from solution calorimetry experiments.

Values for the enthalpies of dissociation of the calcium chloride ammoniates were also determined: 10.6 $\pm$ 0.07, 10.04 $\pm$ 0.08, 16.2 $\pm$ 0.2, and 18.7 $\pm$ 0.2 kcal mol^{-1} NH_3 for $CaCl_2 \cdot 8NH_3$, $CaCl_2 \cdot 4NH_3$, $CaCl_2 \cdot 2NH_3$, and $CaCl_2 \cdot NH_3$, respectively. These data confirm previously reported for $CaCl_2 \cdot 8NH_3$ and $CaCl_2 \cdot 4NH_3$ and establish reliable values for $CaCl_2 \cdot 2NH_3$ and $CaCl_2 \cdot NH_3$.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: AIR COOLED ABSORPTION CHILLERS FOR SOLAR COOLING APPLICATIONS

PRIN. INVESTIGATOR: WENDELL BIERMANN

ORGANIZATION: CARRIER CORP.
ESD

ADDRESS: CARRIER TOWER
P.O. BOX 4800
SYRACUSE, NEW YORK 13221

TELEPHONE NO.: (315) 424-4626

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,232,880

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-77CS 31587

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1977 **THROUGH** OCTOBER 1982

PROJECT OBJECTIVES: The purpose of this program is to identify the chemical composition of a "best" absorption-refrigerant system, capable of being air cooled to determine those properties of the system necessary to design hot water operated, air cooled equipment and to design and operate air cooled chillers from single family residential sizes into the commercial rooftop size range.

PROJECT DESCRIPTION AND STATUS: Three ton unit developed using chemical composition for air cooled absorption chiller. COP of 0.76. Designate as Prototype I.

Survey possible absorbent-refrigerant combinations and select most promising candidate system for development of air-cooled absorption chiller suitable for solar cooling. Part I. Organic Absorbent Systems 1/78; Part II. Solid Absorbents; High Latent Heat Refrigerants 4/78; Lithium Salts with Anti-freeze Additives 6/78.

Make numberical measurements of vapor pressures, relative enthalpies, specific heat capacities, viscosities, thermal conductivities, heat transfer coefficients and other basic design quantities.

Design and construct 10kw (3 ton) air cooled absorption chiller incorporating Prototype I experience, and 1) use shell and tube evaporator, 2) have provision for "winterizing", 3) reduce fan power. Designate at Prototype II.

Supply two 10kW Prototype II chillers to Arizona State Univ. and Colorado State Univ. for field testing operation.

Design and construct 70kw (20 ton) air cooled absorption chiller based on Prototype II scale-up.

At the present writing 3 chillers have been constructed and 2 operated under test conditions. The first of these, a "breadboard" type construction, produced about 8kw (2.3 t) of cooling at the design point of 110°C (230°F) hot water entering the generator, 35°C ambient air and 7.2°C (45°F) chilled water to the load. This served to vindicate the basic design concepts and refined some of the heat transfer coefficient data.

2 Additional pieces of equipment, a 10kW prototype single family residential unit and a 35kW rooftop solar package (built with funding from SERI as part of the SOLERAS program) have been constructed. In neither case has the projected capacity and thermal efficiency been realized as yet. Additional testing is in progress to identify the problem areas and take appropriate remedial measures.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 and 240,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Lithium Bromide and Ethylene Glycol/water/hot water 230/air

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 95/45

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.74

PROJECT SUMMARY

PROJECT TITLE: WATER-COOLED ABSORPTION CHILLERS FOR SOLAR COOLING APPLICATIONS

PRIN. INVESTIGATOR: W.J. BIERMANN/R.C. REIMANN

ORGANIZATION: ENERGY SYSTEMS DIVISION
CARRIER CORPORATION

ADDRESS: CARRIER TOWER
P.O. BOX 4800
SYRACUSE, NY 13221

TELEPHONE NO.: (315) 424-4626

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,718,177

SOURCE(S)	LEVEL (%)
BONNEVILLE POWER ADMINISTRATION (BPA)	1,223,959
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	494,218

CONTRACT NO.: BPA: 14-03-6280N/DE-AC79-79BP10467
NASA: DEN 8-000007/DEN 8-000015

CONTRACT AGENCY: BPA/NASA

CONTRACT PERIOD:

FROM 1977 **THROUGH** 1982

PROJECT OBJECTIVES: The long-term objective of the program which has been implemented by a series of project grants by the agencies enumerated above was the development of a broad line of absorption chillers designed to operate with hot fluids at as low a temperature as practical while rejecting heat to a stream of water. A second objective was to develop a packaging concept for solar application in which controls, pumps, valves, and other system components could be factory-assembled into a unitary solar module.

PROJECT DESCRIPTION AND STATUS: A design point was selected on the basis of what might reasonably be expected from a system using good quality flat plate solar collectors. Specifically, we chose:

Rating Conditions: Hot water 82°C (180°F) and 0.060 l is $^{-1}$/kW capacity (3.33 gpm/ton (c))
Cooling water 29°C (85°F) and 0.126 l is $^{-1}$/kW (c) (7.00 gpm/ton (c))
Chilled water 7.2°C (45°F) and 0.043 l is $^{-1}$/kW (c) (2.40 gpm/ton (c))

Size Range: 50-500 kW (c) (15-150 tons); smaller units to be contained in preassembled solar packages.

A low temperature absorption chiller has been designed, laboratory tested, and field tested. It is suitable for solar, geothermal, or energy recovery applications. The manufacturability of the low temperature chiller has been demonstrated on a commercial production line. The low temperature chiller design includes 15 tons, 75 tons, and 130 tons. Packaging of the 15-ton size chiller into a simple unitary solar package has been done. The 15-ton chiller was installed and monitored for one year at Ross Control house, Vancouver, WA, with a steam auxiliary at Tyler, TX, with an electric-driven heat pump as auxiliary at Big Eddy control house, Dalles, OR, and with improvements and tracking concentration through collectors at the BDP Distribution Center, Phoenix, AZ, The 130-ton chiller is a scale-up of the 15-ton chiller and installed in the Frenchman's Reef Holiday Inn, American Virgin Islands. Two 75-ton chillers based on the same design as the 130-ton chiller will be designed, constructed, and tested at Houston, TX, and Las Vegas, NV.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 180,000-1,560,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Water/solar/air and water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 85/45

STEADY-STATE C. O. P. AT DESIGN TEMP.: 0.72

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF NEW FLUIDS FOR SOLAR ABSORPTION COOLING

PRIN. INVESTIGATOR: ROBERT MACRISS

ORGANIZATION: INSTITUTE OF GAS TECHNOLOGY

ADDRESS: 3424 South State Street
Chicago, IL 60616

TELEPHONE NO.: (312) 567-3650

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 97,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-77CS 31439
OLD NO. EG-77-C-03-1439

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1977 **THROUGH** OCTOBER 1978

PROJECT OBJECTIVES: To develop new fluids for solar absorption cooling systems.

PROJECT DESCRIPTION AND STATUS: Primarily an experimental and analytical project. The three major tasks were to:

1. Identify, screen and make preliminary selection of potential candidate fluid systems.
2. Develop data to evaluate the most promising candidates.
3. Use the data to project the COP's of solar absorption cooling cycles employing the new fluids.

Over 100 potential refrigerants and over 100 potential absorbents were screened. Among these, six groups of refrigerants were selected for further consideration resulting in about 100 potential refrigerant-absorbent combinations. Results of this work may be found in NTIS publication SAN-1439-8.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: DESIGN OF A SOLAR AIR CONDITIONER USING A SOLID-PHASE ABSORBENT

PRIN. INVESTIGATOR: P. O'D. OFFENHARTZ

ORGANIZATION: EIC CORPORATION

ADDRESS: 55 CHAPEL STREET
NEWTON, MA 02158

TELEPHONE NO.: (617) 964-2710

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 160,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-77C34537

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1977 **THROUGH** SEPTEMBER 1978

PROJECT OBJECTIVES: To design, construct, and test a solar air conditioner based on solid-phase absorption.

PROJECT DESCRIPTION AND STATUS: Solid-phase absorption air conditioning offers two important potential advantages over conventional lithium bromide systems: built-in storage so that an auxiliary thermal storage tank is not required, and higher heat rejection temperatures so that dry air heat exchange can replace the cooling tower. To develop a practical air conditioner based on solid-phase absorption, it is first necessary to find a suitable chemical reaction and then to design an appropriate heat exchange system. The absorber is to be a low-cost inorganic salt which provides air conditioning by reacting with water vapor. The thermodynamics and kinetics of the reaction are to be chosen such that dry-air heat rejection can be accomplished while maintaining relatively low solar collector temperatures and a coefficient of performance (COP) above 0.60. Sufficient thermal storage is to be provided in the dehydrated absorber to permit essentially 100 percent solar operation, without utility backup. The reaction of calcium chloride monohydrate ($CaCl_2/H_2O$) to produce calcium chloride dihydrate has been selected for development. No side reactions have been found, and the reaction appears completely reversible. EIC has developed a preliminary heat exchanger design that is compact, low in cost, and relatively easy to construct. The reaction of $CaCl_2/H_2O$ appears to meet design objectives. The projected COP of the air conditioner is 0.70, and may be increased significantly if the heat exchanger weight and thermal capacitance can be reduced.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Calcium chloride monohydrate (solid-phase absorption)

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) Solar 100-200°C

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ANALYSIS OF ADVANCED CONCEPTUAL DESIGNS FOR SINGLE FAMILY SIZED ABSORPTION CHILLERS

PRIN. INVESTIGATOR: ROBERT LACEY

ORGANIZATION: SOUTHERN RESEARCH INSTITUTE

ADDRESS: 2000 NINTH AVENUE, SOUTH
BIRMINGHAM, ALABAMA 35205

TELEPHONE NO.: (205) 323-6592

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 114,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-77CS 31586

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1977 **THROUGH** AUGUST 1978

PROJECT OBJECTIVES: Was to find means of improving the performance or reducing the cost of a solar-powered absorption chiller in the size range of 3 tons.

PROJECT DESCRIPTION AND STATUS: An investigation of new refrigerant/absorbent (R/A) pairs, additives to currently used R/A pairs, and modifications to the cycle, were conducted to improve performance and/or reduce cost of a solar powered absorption chiller. The research consisted of five tasks: 1) literature search, 2) definition of criteria, 3) analysis of conceptual designs, 4) comparison and selection of promising systems, 5) recommendations.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Solar 160°F to 230°F

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: UNITARY SOLAR HEATING/COOLING SYSTEM PACKAGE DEVELOPMENT

PRIN. INVESTIGATOR: RICHARD MERRICK

ORGANIZATION: ARKLA INDUSTRIES
P.O. BOX 534

ADDRESS: EVANSVILLE, IN 47704

TELEPHONE NO.: (812) 424-3331

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $1,304,488

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-77CS 34593

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM JUNE 1977 **THROUGH** DECEMBER 1981

PROJECT OBJECTIVES: To develop 3 ton residential and 25 ton commercial unitary solar heating and cooling system hardware and software.

To develop an evaporatively cooled 3 ton lithium bromide absorption chiller and establish its reliability and manufacturability.

To add a double effect, gas fired auxiliary mode of operation to the evaporatively cooled chiller creating a dual solar/gas unit.

PROJECT DESCRIPTION AND STATUS: Commercialization of a 3 ton solar package has been achieved. Operation has led to system improvements and cost reduction of this product.

A 25 ton unitized package has been developed and successfully tested.

Develop an evaporatively cooled absorption chiller and establish its reliability and manufacturability. Elimination of the separate cooling tower reduces first cost, installation cost and parasitic power.

To add a double effect, the gas fired auxiliary mode of operation is added to the evaporatively cooled chiller creating a dual solar/gas unit.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000 residential; 300,000 commercial

WORKING FLUID/HEAT SOURCE/HEAT SINK: Lithium Bromide/water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) Res - 78 wb air/45 water; com'l - 85/45 water

STEADY-STATE C. O. P. AT DESIGN TEMP.: Res - .72 solar, 1.0 gas; com'l - .68 solar

PROJECT SUMMARY

PROJECT TITLE: CALCIUM CHLORIDE-METHANOL CHEMICAL HEAT PUMP FOR SOLAR HEATING AND COOLING

PRIN. INVESTIGATOR: PETER O'D. OFFENHARTZ

ORGANIZATION: EIC LABORATORIES, INC.

ADDRESS: 55 CHAPEL STREET
NEWTON, MA 02158

TELEPHONE NO.: (617) 965-2710

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 618,300

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 490105-S

CONTRACT AGENCY: BROOKHAVEN NATIONAL LABORATORY

CONTRACT PERIOD:

FROM April, 1977 **THROUGH** September, 1980

PROJECT OBJECTIVES: To design, construct and field test a solar-activated chemical heat pump for residential heating, cooling, and domestic hot water, incorporating adequate (chemical) storage for overnight heating and late afternoon/early evening cooling. Heat rejection in summer should not require a cooling tower, and the system should be capable of meeting the full heating load at or below 25°F ambient air temperature.

PROJECT DESCRIPTION AND STATUS: The research segment of this project has focused on determining the thermodynamic and kinetic behavior of the $CaCl_2$-CH_3OH reaction, as well as the extent of corrosion and side reaction. It has been determined that practical heat pumping rates are feasible at an absorber-evaporator temperature difference above 100°F, making the cycle exceptionally well suited to space heating in central and northern climates, as well as cooling with dry-air heat rejection. A detailed thermodynamic analysis indicates COPs of 0.6 for cooling and 1.6 for heating. The reaction components are strictly noncorrosive toward copper and aluminum, and no side reactions occur. $CaCl_2$ pellet size has been optimized, and it has been determined that the pellets will cycle without chemical or physical degradation.

The hardware development effort has focused on the $CaCl_2$ heat exchanger, which is the key element in the design. A 1/3 scale unit has been constructed and tested; the experimental cooling COP is 0.52, in excellent agreement with the theoretical analysis. The original heat exchanger design showed some distortion due to salt expansion and contraction, but this problem has been overcome by stiffening the salt-bed container. The conceptual design for a full-scale system has been completed, specifications have been prepared for all components, and a control system has been worked out. The next stage of work is the detailed design, construction and field testing of a solar-activated unit.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	30,000 (cooling); 32,000 (heating)
WORKING FLUID/HEAT SOURCE/HEAT SINK:	CH_3OH/air/air
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	115°/45° (cooling); 105°/15° (heating)
STEADY-STATE C. O. P. AT DESIGN TEMP.:	0.6 (cooling); 1.6 (heating)

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF SOLAR DRIVEN ABSORPTION AIR CONDITIONERS

PRIN. INVESTIGATOR: KIM DAO

ORGANIZATION: LAWRENCE BERKELEY LAB.
1 CYCLOTRON ROAD

ADDRESS: BERKELEY, CA 94720

TELEPHONE NO.: (415) 486-6798

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ PART OF $1,372,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: W-7405-ENG-48

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM OCTOBER 1976 **THROUGH** SEPTEMBER 1986

PROJECT OBJECTIVES: The objective of this project is to develop absorption-cycle refrigeration systems that achieve significantly higher seasonal conversion efficiencies than is possible using other cooling approaches. A secondary objective is to avoid the necessity for water cooling towers by using air-cooled condensers and absorbers.

The quest for higher conversion efficiencies is one of the approaches leading toward eventual achievement of cost-effective solar cooling systems by the solar industry. The major cost component of a solar cooling system is the collectors; the collector area required to satisfy a given load can be reduced (lowering costs) as the efficiency of the chiller component is increased.

PROJECT DESCRIPTION AND STATUS: Develop a higher efficiency chiller, yet one with less hardware. This chiller is based on a single effect regenerative cycle. This chiller is in an early design stage. The success of this chiller depends on locating a refrigerant/absorbent fluid pair with suitable properties at the higher boiling temperatures.

Development of an advanced higher efficiency cycle, a double effect regenerative cycle that adds a unique second stage to the chiller. With the addition of this second stage, the overall chiller efficiency increases continuously as a function of the inlet temperature from the solar collectors.

Design and fabrication of a single effect absorption chiller that incorporates tube-in-tube heat exchangers, an internally powered solution pump for reduced parasitic power use, and a rectification path for the hot vapor generated.

Partial reconstruction for solar-powered operation of a conventional gas-fired ammonia/water absorption chiller. It demonstrated the capability to predict accurately the performance of single effect absorption chillers under operating conditions appropriate for solar powered operation.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Solar, single effect

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: THE OPERATIONAL ENVELOPE OF SOLAR POWERED ABSORPTION HEAT PUMPS

PRIN. INVESTIGATOR: NOAM LIOR

ORGANIZATION: UNIVERSITY OF PENNSYLVANIA
III TB-D3

ADDRESS: PHILDELPHIA, PA

TELEPHONE NO.: (215) 243-4803

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ PARTIAL NSF-RANN GI 29779

SOURCE(S)	LEVEL (%)
UNIVERSITY OF PENNSYLVANIA	LOW

CONTRACT NO.: GI 29779

CONTRACT AGENCY: NSF/RANN

CONTRACT PERIOD:

FROM 1972 **THROUGH** 1975(?)

PROJECT OBJECTIVES: 1) First- and second-law analysis of absorption heat pumps, to determine limits of operation, both ideal and realistic.

2) Fundamental studies in multi-stage flash evaporation, for possible application with multi-effect absorption heat pumps.

PROJECT DESCRIPTION AND STATUS: 1) Perform thermodynamic analysis to determine the absorption heat pump-solar collector combination characteristics which result in a saving of collector area by using such a heat pump in lieu of a direct solar heating system. Energy analysis of absorption heat pumps was conducted.

2) Analysis and experiments in flash evaporation were conducted which showed relevance to multi-effect absorption heat pumps.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: GAS- OR SOLAR-FIRED RESIDENTIAL HEAT PUMP USING A VARIABLE EFFECT PROCESS

PRIN. INVESTIGATOR: KEN KAUFFMAN

ORGANIZATION: ABSORPTION PROCESS TECHNOLOGY

ADDRESS: 4920 CITY LINE AVE., #A207
PHILADELPHIA, PA 19131

TELEPHONE NO.:(215 - 473-7905
448-1549
448-1183 **)**

SUBCONTRACTOR: (if applicable) FRANKLIN RESEARCH CENTER
DAVID ARONSON ASSOCIATES
JOHNSON ENGINEERING COMPANY

TOTAL FUNDING: $ Unavailable

SOURCE(S)	LEVEL (%)
SELF-FUNDED	100

CONTRACT NO.: PRIVATELY FUNDED

CONTRACT AGENCY: NOT APPLICABLE

CONTRACT PERIOD:

FROM _____ **THROUGH** _____

PROJECT OBJECTIVES: 1. To build and performance test a 3 ton (cooling) engineering prototype. 2. To refine the design and construct prototypes. 3. To field test the prototypes and demonstrate for manufacturer licensing.

PROJECT DESCRIPTION AND STATUS: A new process and machine concept for absorption heat pumping are being developed. The variable effect machine attains the performance of single-effect, multi-effect, or anywhere in between. Triple-effect is attained with mild winter conditions. The process matches the application, that heat exchange with air streams occurs over a range of temperature, and that the outdoor temperature varies widely over time. The machine uses a slowly rotating thin film heat exchanger for efficiency, compactness, and low cost.

The design of a 3 ton (cooling) engineering prototype has been completed. Funding is being sought for building and testing the prototype, and for its commercial development.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) 36,000

WORKING FLUID/HEAT SOURCE/HEAT SINK: Supersalt and water with fluoroethanol

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) 110°F/45°F

STEADY-STATE C. O. P. AT DESIGN TEMP.:

SECTION 9

CROSS-CUTTING AND OTHER PROJECTS

(26 PROJECTS)

PROJECT SUMMARY

PROJECT TITLE:

ANALYSIS OF NON-VAPOR-COMPRESSION HEAT PUMP CYCLES

PRIN. INVESTIGATOR: William M. Toscano

ORGANIZATION: Foster-Miller Associates, Inc.

ADDRESS: 350 Second Avenue
Walthan, MA 02154

TELEPHONE NO.: (617) 890-3200

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-8949

CONTRACT NO.: RP2033-3

CONTRACT AGENCY:
Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 2/10/82 **THROUGH** 11/10/82

PROJECT OBJECTIVES:

This work seeks to identify heat pump concepts warranting further research and development efforts to:

- Improve performance (particularly for operation at low ambient temperatures),
- Improve load characteristics to utilities, and
- Offer alternatives to chlorofluorocarbon refrigerant, vapor-compression cycles.

PROJECT DESCRIPTION AND STATUS:

The feasibility of electrically-driven,non-vapor-compression (modified Rankine) cycle heat pump concepts are being evaluated. The study examines reverse Brayton and Stirling cycles as well as other concepts. A literature search, screening of concepts, feasibility analysis, and economic analyses are included. Commercially available heat pumps generally utilize the vapor-compression refrigeration cycle as the means of transferring heat from a low-temperature source to a high-temperature sink. Chlorofluorocarbon working fluids are used almost exclusively in these heat pumps for space conditioning and water heating applications. An extensive amount of literature exists on prime movers using electrically driven heat pumps. Recent investigations have suggested that alternative cycles may offer advantages at low-source temperatures.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

HEAT PUMP MANUAL

PRIN. INVESTIGATOR: Jeffrey M. Seisler

ORGANIZATION:

ADDRESS: 215 North West Street
Alexandria, VA 22314

TELEPHONE NO.: (703) 836-7692

SUBCONTRACTOR: (if applicable) Dr. Ronald H. Howell
Dr. Harry J. Sauer, Jr.
University of Missouri

EPRI PROJECT MANAGER:
James M. Calm
(415) 855-8949

NRECA PROJECT MANAGER:
Lowell Endahl
(202) 857-9598

CONTRACT NO.: RP2033-7

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 1/19/82 **THROUGH** 7/31/82

PROJECT OBJECTIVES:

The purpose of this project is to prepare a manual, as well as a brochure and news article, on heat pumps. These documents are intended to provide understandable answers to common questions on heat pumps and a guide to their application. Air-, water-, and ground-source systems as well as hybrid and solar assisted heat pumps will be addressed.

PROJECT DESCRIPTION AND STATUS:

A reference manual for use by utility customer-service representatives and application engineers will be prepared. The manual will address the various systems available and provide a source of information on:

- What a heat pump is,
- What it does,
- What equipment is available,
- Which type are best suited for representative residential applications,
- How to size heat pump systems,
- How to estimate energy consumption,
- How to compare costs of heat pumps to alternative systems,
- Operational tips to maximize energy conservation (e.g., insulation and night setback),
- Operation in tandem with other heating systems,
- Considerations in selecting equipment for specific application, and
- Sources of further information.

A brochure will also be prepared for utility distribution to homeowners to provide summary information on heat pumps in a simple form. Copy material for a news article on heat pumps will also be prepared for utility use.

This is a new project jointly funded by EPRI and the National Rural Electric Cooperative Association (NRECA).

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

Gas-Fired Heat Pump Research and Development - Review and Assessment

PRIN. INVESTIGATOR: J. Wurm

ORGANIZATION: Institute of Gas Technology

ADDRESS: 4201 West 36th Street
Chicago, Illinois 60632

TELEPHONE NO.: (312) 567-3839

SUBCONTRACTOR: (if applicable)

N/A

TOTAL FUNDING: $ Not Available

SOURCE(S) **LEVEL (%)**

CONTRACT NO.: 5081-242-0541

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 13 months

FROM September 1981 **THROUGH** October 1982

PROJECT OBJECTIVES: Compile and analyze, from public and private sources, information on research investigations or proposed investigations on gas-fired air-conditioning and gas-fired heat pumps. The information is to be formatted to provide the research sponsors, research investigators, and the gas industry with a ready source of information for assessing the potential of current and future research and developmental efforts on gas-fired air-conditioning and gas-fired heat pumps.

PROJECT DESCRIPTION AND STATUS: One of the greatest hindrances to the rapid development of gas-fired heat pumps has been the lack of a compendium of knowledge of what had already been done or tried over the years. This bibliography would greatly accelerate development of prime mover systems, selection of refrigerants, and improvement of reliability and performance by putting years of related experience at the developer's fingertips. Utilization of the knowledge and techniques used by the electric heat pump industry to solve the reliability problems it faced will make it possible for the gas heat pump industry to avoid the same pitfalls and gain the respect of the consumer that much sooner.

The GRI heat pump project advisors made known the need of a documented record of heat pump knowledge. Most of this information has never been satisfactorily pulled together.

This information will then be compiled into an annotated bibliography in a format designed to facilitate information retrieval. A useful bibliography will aid in accelerated R&D of new and present gas-fired heat pump systems. Also, the gas consumer may benefit from a more reliable, better performing product.

The format of the annotated bibliography will be designed to make it highly useful. Selected entries will be provided with a short assessment or explanatory note and will be indexed and cross-referenced. A system will derived to facilitate effective information retrieval.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: N/A
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SPACE CONDITIONING PERFORMANCE ANALYSIS AND SIMULATION STUDY

PRIN. INVESTIGATOR: U. BONNE

ORGANIZATION: HONEYWELL, INC.

ADDRESS: 10701 LYNDALE AVE. S.
BLOOMINGTON, MN 55420

TELEPHONE NO.: (612) 887-4477

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 100,000.

SOURCE(S)	LEVEL (%)
GAS RESEARCH INSTITUTE	100

CONTRACT NO.: 5014341-0144

CONTRACT AGENCY: GAS RESEARCH INSTITUTE (GRI)

CONTRACT PERIOD:

FROM MAY 1, 1981 **THROUGH** MARCH 31, 1982

PROJECT OBJECTIVES: The objective of this program is to prepare a comprehensive report that documents the performance characteristics and the various factors that influence system performance of advanced and conventional space conditioning systems.

PROJECT DESCRIPTION AND STATUS: Performance simulations using computer codes are used to project system performance and cost savings in terms of energy savings for advanced and conventional heating and cooling systems. The advanced systems are gas-fired engine driven heat pumps and gas-fired absorption heat pumps. The conventional system uses an electric driven heat pump with supplemental gas heating for the heating mode. Supplemental gas heating is also utilized with the absorption and engine driven systems.

Honeywell proprietary codes: HFLAME and HFROST, are being used to study conventional systems; HSPARK, to study engine driven systems; and HSORB to study the absorption systems. The analysis is being used to study the effects of component sizes and efficiencies, electric power and gas consumption, mode of operation, climate, refrigerant circuit features, unit cycling and controls, and unit losses, on overall system performance and cost efficiency. Cost efficiency, which is used as a ranking parameter for the various heat pump systems, is defined as the ratio of net space conditioning system output to the equivalent gas input (normalized to account for electric power consumption).

Additional factors being analyzed include the benefits from integrating space heating and water heating functions and the effects of barriers or standards to efficient use of natural gas.

Work has been completed on the engine driven and conventional systems and steady state analyses have been completed on the absorption systems. Work on the comprehensive report is approximately one-third complete.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

ASSESSMENT OF UNITARY HEAT PUMPS

PRIN. INVESTIGATOR: Morton H. Blatt

ORGANIZATION: Science Applications Inc.
Energy Systems and Conservation Division

ADDRESS: 1200 Prospect Street
P.O. Box 2351
La Jolla, CA 92038

TELEPHONE NO.: (714) 454-3811

SUBCONTRACTOR:
(if applicable)

EPRI PROJECT MANAGER:
James M. Calm
Project Manager, Heat Pump Development
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 895-8949

CONTRACT NO.: RP1495-2

CONTRACT AGENCY: Electric Power Research Institute (EPRI)

CONTRACT PERIOD:

FROM 1/15/81 **THROUGH** 9/30/82

PROJECT OBJECTIVES:

The objectives of this project were to :

- Assess the technology status of electric heat pumps,
- Survey regulatory issues affecting heat pumps,
- Summarize the market status of heat pumps, and
- Identify future research and development needs.

PROJECT DESCRIPTION AND STATUS:

This project involved a survey of technical literature, contacts with heat pump manufacturers and trade associations for information about new heat pump concepts and technology trends, and compilation and analysis of market data. The status and effect of federal building energy efficiency, consumer product efficiency, chlorofluorocarbon production, and other regulations were reviewed. Special technical issues, such as speed modulation, defrost mechanisms, and controls were investigated and recommendations regarding future research and development needs were made.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: Advanced Positive Displacement Rotary Vapor Compression Heat Pump

PRIN. INVESTIGATOR: Ralph Hoffman

ORGANIZATION: Trochoid Power Corporation

ADDRESS: 14789 Martin Drive
Eden Prairie, MN 55344

TELEPHONE NO.: (612) 937-9163

SUBCONTRACTOR: (if applicable) None

TOTAL FUNDING: $ 316,207

SOURCE(S)	LEVEL (%)
GRI	81
Trochoid	19

CONTRACT NO.: N/A

CONTRACT AGENCY: GRI

CONTRACT PERIOD: 15 Months

FROM January 1981 **THROUGH** April 1982

PROJECT OBJECTIVES: The objectives for developing an advanced positive displacement rotary vapor compressor are:

- economy and ease of manufacture
- high volumetric and compression efficiencies
- economy of power consumption over a range of compression ratios
- high speed operation
- high durability

PROJECT DESCRIPTION AND STATUS: As of October 15th, a single rotor unit of approximately 300 lbs/hr capacity has been designed and detailed. The program is on schedule for final assembly about January 1, 1982. A mathematical model has been developed covering the cycle analysis and critical operating characteristics. Extensive tests have been conducted on wear rates and coefficients of friction, and although a final match has not been determined, it is certain that one of the following four combinations will be used in the proof-of-concept unit. (1) Grey iron rotor using either a carbon seal or a teflon-bronze seal. (2) A Tribaloy coated grey iron rotor using either a grey iron seal or a carbon seal.

The test unit is approximately 14"x14"x7", designed to run at 3450 rpm. Contrary to piston compressors of the same capacity, it will be smaller than the 20 horsepower motor driving it. The unit has a waterjacket for instrumentation of heat transfer.

As of March, 1982 it is expected that compression ratios varying from 1:1 through 8:1 will have been evaluated using saturated steam at 14.7 psia inlet pressure. Studies will also have been concluded relating to the maximum capacity for a given unit. Upper limits in size will be limited by sonic velocities of the steam being compressed, and maximum machining facilities offering CNC capabilities for machining the trochoidally shaped rotor and outer-envelope housing. A further constraint is the maximum allowable rubbing velocities of the chosen seal material.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ANALYSIS OF ACTIVE SOLAR ABSORPTION AND RANKINE COOLING SYSTEMS FOR RESIDENTIAL AND COMMERCIAL BUILDINGS.

PRIN. INVESTIGATOR: J. MOREHOUSE

ORGANIZATION: SCIENCE APPLICATIONS, INC. (SAI)

ADDRESS: 1710 GOODRIDGE DRIVE
McLEAN, VA 22102

TELEPHONE NO.: (703) 827-4915

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 242,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-81SF11573
(OLD) XB-0-9145-1

CONTRACT AGENCY: DOE/SAN

CONTRACT PERIOD:

FROM September 1980 **THROUGH** September 1982

PROJECT OBJECTIVES: To analyze the performance and economics of state-of-the-art absorption and Rankine systems on a comparative basis with conventional systems.

To modify computer program to effectively model the system operation of absorption and Rankine solar cooling systems, using state-of-the-art chillers, storage, collectors and control strategies.

PROJECT DESCRIPTION AND STATUS: SAI has previously done a preliminary analysis comparing absorption and Rankine systems. This study is an extension that will analyze residential and commercial sizes of both technologies on a performance and cost basis against competing conventional systems in order to both assess their status and help formulate program goals. As part of this task, updated cooling system simulation models will be developed and baseline thermodynamic studies will be performed.

A TRNSYS compatable computer model was developed to stimulate seasonal operation of active solar cooling systems. Specific component performance data were used to input the program. Results of this study will be used in the active program research requirement task (APRR).

About 50% of the cooling system analysis has been completed, all of the proposed systems are to be completed by July 1982. The APRR central coordinator activity is to be completed by September 30, 1982.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: RD&D OPPORTUNITIES FOR LARGE HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: DAVID GOLDENBERG

ORGANIZATION: TRW

ADDRESS: 800 OAK RIDGE TURNPIKE
BUILDING B
OAK RIDGE, TENNESSEE 37830

TELEPHONE NO.: (615) 482-9054

SUBCONTRACTOR: (if applicable) W. S. FLEMING AND ASSOCIATES
TWO METRO PLAZA
LANDOVER, MARYLAND 20785

HARRY MISURIELLO
(301) 459-3565

TOTAL FUNDING: $ 110,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: 62B-13817C

CONTRACT AGENCY: OAK RIDGE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM SEPTEMBER, 1980 **THROUGH** JULY, 1981

PROJECT OBJECTIVES: This study concerns large capacity heat pump/air conditioning (A/C) equipment and systems for environmental conditioning in the commercial sector. The objectives are to: establish existing populations of A/C equipment and commercial buildings; describe A/C equipment market sizes; compare the relative energy use of systems; assess the effects of non-technical factors on the development and increased use of energy efficient A/C equipment and systems; assess the opportunities for RD&D work leading to improvements or increased use of energy efficient equipment or systems; and formulating recommendations for RD&D activities in these areas.

PROJECT DESCRIPTION AND STATUS: A relatively successful research, design, and development (RD&D) effort by government and industry for residential heat pump equipment is well under way. This study provides descriptions and assessments of A/C equipment and systems in the commercial milieu to be used for initial planning of RD&D activities pertaining to the commercial sector.

Use of currently available equipment and systems which are energy efficient is limited by the economic situation of building owners. Increasing energy prices do not show much potential for changing this situation. Case histories of energy efficient buildings (in available literature) highlight the potential of existing equipment and systems, but the majority of systems (and equipment) being installed in commercial buildings do not measure up to this potential. A program of market development is needed before development of the next generation of A/C equipment and systems will hold much promise.

The high priority recommendations of this study deal with development of the market for energy efficient HVAC systems and equipment by reversing existing market forces which promote energy consumption. Second priority recommendations deal with technical research and educational programs covering research of systems application and operation, increasing the number of technical people who are competent in the area of energy system efficiency improvement, and other areas. The work on A/C equipment and commercial buildings populations is continuing.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

not applicable

PROJECT SUMMARY

PROJECT TITLE: EAST Facility Requirements Documentation

PRIN. INVESTIGATOR: F. Joseph McCrosson

ORGANIZATION: South Carolina Energy Research Institute

ADDRESS: 1401 Main Street
Suite 670
Columbia, S.C. 29201

TELEPHONE NO.: (803) 256-6400

SUBCONTRACTOR: (if applicable)

Mechnical Technology, Inc.
2731 Prosperity Avenue
Fairfax, VA 22031
Robert H. Badgley (703) 698-9000

United Technologies Research Center
East Hartford, CN 06108
Frank R. Biancardi (203) 727-7234

TOTAL FUNDING: $ 485,604

SOURCE(S)	LEVEL (%)
Department of Energy	100%

CONTRACT NO.: DE-AC09-77ET12866

CONTRACT AGENCY: Savannah River Operations Office

CONTRACT PERIOD:

FROM 9/1/80 **THROUGH** 7/31/81

PROJECT OBJECTIVES: To develop and document the initial design requirements for the proposed Energy Applied Systems Test (EAST) Facility at the Savannah River Plant, Aiken, S.C.

PROJECT DESCRIPTION AND STATUS: Development of the EAST Facility requirements was one element of the Energy Department's Residual Energy Application Program (REAP) to recover large quantities of residual energy at Federal nuclear facilities and to stimulate waste heat recovery in the private sector. The proposed government-owned, contractor-operated EAST Facility would provide development and confidence testing for industrial heat pumps, absorption chillers, and Rankine-cycle power generation systems. The core EAST Facility would simulate waste streams in the range 100-1000°F and would be capable of around-the-clock multi-system/subsystem testing of two 0.5 to 2.0 MW power generation systems and two 5 to 50 million Btu/hr heat pump systems (alternatively, one 2 to 6 MW PGS and one 50 to 100 million Btu/hr HP).

The decision to construct the facility has not been made by DOE.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: INDUSTRIAL PROCESS HEAT PUMP SERVICE STUDY

PRIN. INVESTIGATOR: W. F. KNIGHTLY

ORGANIZATION: GENERAL ELECTRIC COMPANY

ADDRESS: BUILDING 23, ROOM 116
1 RIVER ROAD
SCHENECTADY, N.Y. 12345

TELEPHONE NO.: (518) 385-4988

SUBCONTRACTOR: NONE
(if applicable)

TOTAL FUNDING: $ 320,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC02-80CS40449

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM AUG. 18, 1980 **THROUGH** APRIL 30, 1982

PROJECT OBJECTIVES: Assess the potential energy savings of high temperature heat pumps (230°F-400°F) in different industries (SICs) and at the national level. Estimate the economic market and fuel savings.

PROJECT DESCRIPTION AND STATUS: The 108 processes identified in the DOE industrial data base have been matched to various heat pump cycles (open, partially-open, and closed). System performance (COP, fuel savings, horsepower) and capital cost (of compressors, flash tanks, heat exchangers) have been used to develop the economic attractiveness of each match. Results are tabulated by SIC and net fuel savings (including increased utility fuel usage) and summarized.

Surveys were made of nine sites in the pulp and paper industry, and one site in the pulp and paper industray and one site in the chemical industry were chosen for detailed preliminary design studies.

The overall project is 90% complete.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: N/A
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: GROUND COUPLING AND HEAT PUMP COMPATIBLE SOLAR COLLECTORS

PRIN. INVESTIGATOR: JERRY ALCONE

ORGANIZATION: SCIENCE APPLICATIONS, INC.

ADDRESS: 200 LOMAS N.W., SUITE 600
ALBUQUERQUE, NEW MEXICO 87102

TELEPHONE NO.: (505) 247-0381

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 30,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-80CS30219

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM JUNE, 1980 **THROUGH** JUNE, 1981

PROJECT OBJECTIVES: To evaluate existing Ground Coupling Models and Analyses; and to identify and evaluate existing collector systems that are compatible with Solar Heat Pump Systems.

PROJECT DESCRIPTION AND STATUS: A survey will be conducted of existing models and analyses of the storage and/or extraction of thermal energy (heat or cool) from the ground to identify and evaluate for each model or analysis the assumptions used, their validation status, their range of applicability and new research efforts. Also, the survey results shall identify and rank the most promising existing collectors for use in solar heat pump systems, by system type and geographic region. Data from these collectors shall then be analyzed to determine the cost performance characteristics of solar heat pump compatible collectors.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: HEAT PUMP CONCEPTS FOR INDUSTRIAL USE OF WASTE HEAT

PRIN. INVESTIGATOR: HORACIO PEREZ-BLANCO

ORGANIZATION: UNION CARBIDE CORPORATION

ADDRESS: POST OFFICE BOX Y
OAK RIDGE, TN 37830

TELEPHONE NO.: (615) 574-0419

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 28,000.

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: W-7405-eng-26/AA-55-15-15-0

CONTRACT AGENCY: Department of Energy

CONTRACT PERIOD:

FROM 1/80 **THROUGH** 6/80

PROJECT OBJECTIVES: The Waste Heat Recovery Program administered by Oak Ridge National Laboratory has the objective of identifying and developing technology for recovering waste heat at temperatures below 90°C. Under this program, a variety of heat-pumping and refrigerating technologies are being developed by subcontractors. There is also an in-house effort whose overall objective is to identify, screen and develop advanced, high-risk concepts that show adequate potential for waste heat recovery. The present project was carried out as an initial in-house effort in order to identify appropriate research subjects. To this end, the availability of low-grade waste heat throughout the industrial sector and the pattern of process heat demand had to be established. Coupled with this information, a variety of heat-pump technologies geared to recovering the waste heat available and providing process heat had to be analyzed. Two technologies were chosen for further research.

PROJECT DESCRIPTION AND STATUS: The waste heat rejected by the industrial sectors was determined from information available in the open literature. The data are available only at the two digit level of the Standard Industrial Classification (SIC). The profile of process heat vs temperature demand at the same level of aggregation was also determined from data available in the open literature. In the light of this information, it was determined that industrial heat pumps able to provide process heat at about 100°C from waste heat at 60°C (or higher) should find applications in the industrial sector.

Industrial heat pumps may be implemented in any of the following ways: electrically-driven, heat-driven and waste heat-driven. From the standpoint of energy conservation, the heat-driven and the waste heat-driven types were shown to offer the greatest potential. Electrically-driven heat pumps are available in the commercial market, and thus deemed of limited research interest. Therefore, a heat-actuated and two waste heat-actuated heat pump concepts were analyzed.

From this analysis, it was concluded that steam ejector heat pumps offered a low cost, and dependable (albeit inefficient) technology for temperature boosting. Absorption heat pumps, as examples of waste-heat fired concepts, either in a closed or open configuration, were determined to be worthy of further research. It was also established that two-stage absorption heat pumps may be called for in order to meet the desired temperature boosts.

A report entitled "Heat Pump Concepts for Industrial Use of Waste Heat" documenting these findings was issued.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: TECHNICAL ASSESSMENT OF RESIDUAL ENERGY APPLICATIONS AND EAST FACILITIES STUDIES CONCEPTUAL DESIGN OF LARGE SCALE HEAT PUMP FOR CENTRAL ENERGY MANAGEMENT SYSTEM

PRIN. INVESTIGATOR: FRANK R. BIANCARDI
R. W. BASS
A. M. LANDERMAN

ORGANIZATION: UNITED TECHNOLOGIES RESEARCH CENTER

ADDRESS: SILVER LANE
EAST HARTFORD, CT 06108

TELEPHONE NO.: (203) 727-7234

SUBCONTRACTOR: (if applicable) NONE

TOTAL FUNDING: $ $197,800

SOURCE(S)	LEVEL (%)
SOUTH CAROLINA ENERGY RESEARCH INSTITUTE (Subcontract to DOE)	100%

CONTRACT NO.: DE-AC09-77ET12866-Sub-15 (and Sub-20)

CONTRACT AGENCY: SOUTH CAROLINA ENERGY RESEARCH INSTITUTE

CONTRACT PERIOD:

FROM Nov. 1979 **THROUGH** April 1981

PROJECT OBJECTIVES: The objective of this study was to select systems comprised of current and near-term equipment capable of economically recovering 110 to 150 F waste heat from federal facilities, utilities and industries to produce electric power and thermal energy at useful temperatures. At federal facilities and utilities where large amounts of waste heat are available, recovery and distribution of energy is handled by a Central Energy Management System (CEMS) and utilized in an adjacent industrial park. For industrial waste heat recovery, recovered energy is utilized on site.

PROJECT DESCRIPTION AND STATUS: An analytical study was undertaken to identify specific power generation and heat pump requirements for low-temperature waste heat recovery from government, utility and industrial sources, develop techniques needed to evaluate the performance and cost characteristics of various power system and heat pump options, and perform economic analyses on selected designs. Recently completed, DOE-sponsored studies as well as other available literature, were reviewed to define waste heat sources and industrial thermal end-uses. Distinct waste heat sources and industrial end-uses were selected as representative applications and used for heat pump design specifications. Two of these applications typify large sources of waste heat and co-located industrial park end-uses while the remaining four represent in-plant industrial sources and end-uses. Rankine-cycle heat pump configurations and working fluid options were assessed and four configurations were selected on the basis of cost and performance for further study. Five different prime movers were examined as potential compressor drivers and gas turbines and diesels were selected on the basis of high overall performance. A similar design assessment was performed for power recovery systems. A conceptual design of an economically attractive central energy management system for use at an industrial park located nearby the Portsmouth gaseous diffusion plant was made.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)	400×10^6
WORKING FLUID/HEAT SOURCE/HEAT SINK:	R11 & steam/water/steam
DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)	300/150
STEADY-STATE C. O. P. AT DESIGN TEMP.:	1.4

PROJECT SUMMARY

PROJECT TITLE: ENGINEERING FIELD TEST PLANNING

PRIN. INVESTIGATOR: MYRON MYERS

ORGANIZATION: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

ADDRESS: GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER
ALABAMA 35812

TELEPHONE NO.: (205) 453-2051

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 560,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: EX-76-A-29-1024

CONTRACT AGENCY: Department of Energy

CONTRACT PERIOD:

FROM OCTOBER 1979 **THROUGH** SEPTEMBER 1980

PROJECT OBJECTIVES: Develop an engineering field test plan for four of the technologies researched and developed in the System Development Branch of DOE Active Solar Buildings Division.

PROJECT DESCRIPTION AND STATUS: NASA/MSFC analyzed the readiness of Rankine, absorption, desiccant and solar assisted heat pump technologies and developed a plan to move toward marketable solar systems through an engineering field test program.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SOLAR COOLING STUDIES AND SYSTEMS ANALYSIS

PRIN. INVESTIGATOR: DAVE ANAN AND REDFIELD ALLEN

ORGANIZATION: UNIVERSITY OF MARYLAND COLLEGE PARK, MD 20742

ADDRESS:

TELEPHONE NO.: (301) 454-4994

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 219K

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-79CS-30204

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM JULY 1979 **THROUGH** SEPTEMBER 1983

PROJECT OBJECTIVES:

Develop simulation models and computer programs which optimize studies and parametric analysis of cooling machines, cooling system performance and stochastic weather; provide technical support to DOE and conduct specialized research in active solar cooling development.

PROJECT DESCRIPTION AND STATUS:

For both Rankine and absorption (lithium bromide) solar cooling technology areas: integrate the past and current work in component modeling and simulation; continue the cooling system analysis work and transient component modeling and develop a simplified cooling design technique; formulate a methodology for a fair comparative assessment of current projects developing solar absorption chillers and systems; prepare a state-of-the-art paper on absorption cycle fluids; provide technical assistance in reviewing proposals and reports, and in conducting site visits in support of the national solar cooling program; develop an overall systems analysis and testing plan for the System Development Branch, Active Buildings Division research and development activities; and, provide system simulation studies in the photovoltaic-thermal area.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ASSESSMENT OF SOLAR-POWERED COOLING OF BUILDINGS, INCLUDING ANALYSIS OF THERMAL ENERGY STORAGE PARAMETERS FOR SOLAR DRIVEN CHILLERS.

PRIN. INVESTIGATOR: HENRY CURRAN

ORGANIZATION: HITTMAN ASSOCIATES, INC.
9190 RED BRANCH ROAD
COLUMBIA, MD 21045

ADDRESS:

TELEPHONE NO.: (301) 730-7800

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 427K

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: DE-AC03-79CS-30202
DE-AC03-78SF10508 (old)

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM April 1979 **THROUGH** January 1982

PROJECT OBJECTIVES:

Provide technical assistance on the development of active solar cooling technology in three areas: Rankine, absorption, and thermal energy storage.

PROJECT DESCRIPTION AND STATUS:

The Rankine work included: a survey of the organic working fluids used in Rankine engines in the U.S. and other countries; the preparation of a procedure for dynamic stability testing of organic working fluids; and development of performance test plan for Rankine cooling equipment. Additional activities include site visits, review of contractor reports and an evaluation of proposals.

The absorption work included: providing technical input to the solar cooling commercialization readiness assessment; and, providing reviews of contractor reports and the evaluation of proposals.

The storage work included: definition of the operating characteristics of DOE-funded solar cooling equipment, solar collectors suitable for space cooling applications, and thermal storage subsystems; identification of the thermal storage needs and basic design requirements; and identification of needed research and development of solar cooling thermal energy storage.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:

(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE:

HEAT-PUMP-CENTERED INTEGRATED COMMUNITY ENERGY SYSTEMS (HP-ICES)
(DISTRICT HEATING AND COOLING WITH HEAT PUMPS)

PRIN. INVESTIGATOR: JAMES M. CALM, PE

ORGANIZATION: ARGONNE NATIONAL LABORATORY

ADDRESS: ENERGY AND ENVIRONMENTAL SYSTEMS DIVISION
9700 SOUTH CASS AVENUE - BUILDING 11
ARGONNE, ILLINOIS 60439 USA

TELEPHONE NO.: (312) 972-3730

SUBCONTRACTOR:
(if applicable)

35 TOTAL, MAJOR SUBCONTRACTS TO:

UNIVERSITY OF ALABAMA
CONSOLIDATED NATURAL GAS SERVICE COMPANY
DUBIN-BLOOME ASSOCIATES
FRANKLIN RESEARCH CENTER
GEORGIA INSTITUTE OF TECHNOLOGY
HONEYWELL ENERGY RESOURCES CENTER
ROCKET RESEARCH COMPANY

TOTAL FUNDING: $720,000 *

SOURCE(S)	LEVEL (%)
U.S. DEPARTMENT OF ENERGY	100%

* Does not include amounts cost-shared by subcontractors

CONTRACT NO.: W-31-109-ENG-38

CONTRACT AGENCY: DOE/CORO

CONTRACT PERIOD:

FROM October 1978 **THROUGH** March 1981

PROJECT OBJECTIVES: The project sought to conserve energy in the United States by developing heat pump systems for district heating and cooling. Four major activities were included:

- Concept innovation,
- System development,
- Application feasibility studies, and
- System assessment.

The actual development of heat pumps, as compared to systems using heat pumps, was not included in this project.

PROJECT DESCRIPTION AND STATUS: District heating and cooling concepts using centralized, distributed, and cascaded heat pump systems were developed. In fifteen application feasibility studies, using diverse sources and sinks, the systems examined showed promise to:

- Substantially reduce on-site energy use for space heating and cooling and for water heating,
- Substitute nonscarce resources for premium fuels,
- Significantly reduce resultant source-energy use,
- Offer load-management advantages to both electric and gas utilities,
- Reduce adverse environmental impacts, and
- Result in favorable life-cycle costs and, for some systems, payback periods that are shorter than five years.

Because the sources and sinks used are both varied and abundant, broad application potential is believed to exist for these systems.

The results of the project have been reported in 39 publications including a summary and an assessment of the systems developed. Subsequent project phases leading to physical demonstration and commercialization of successful concepts were initially anticipated, but are not presently planned.

The assessment report includes recommendations for further research and development efforts.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

not applicable

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: COMMON STUDY ON ADVANCED HEAT PUMP SYSTEMS

PRIN. INVESTIGATOR: PETER KUEPPERS

ORGANIZATION: KERNFORSCHUNGSANLAGE

ADDRESS: POSTFACH 1913
D-5170
JULICH, GmbH
WEST GERMANY

TELEPHONE NO.:(**)** 011-49-614623

SUBCONTRACTOR: (if applicable)
Battelle - Institut e.v.
AM Romerhof 35
D-6000 Frankfurt am Main 90
West Germany
(Dr. David L. Hodgett)

Resource Planning Associates
50 Church Street
Cambridge, Mass 02138
(Ms. Ann Quinn)

TOTAL FUNDING: $1,507,000 (DM)*

SOURCE(S)	LEVEL (%)
U.S. DOE	27
12 OTHER COUNTRIES VIA INTERNATIONAL ENERGY AGENCY	73

*Deutsch marks

CONTRACT NO.:

CONTRACT AGENCY: INTERNATIONAL ENERGY AGENCY

CONTRACT PERIOD:

FROM October, 1978 **THROUGH** July 1980

PROJECT OBJECTIVES: To collect and evaluate data on advanced heat pump, i.e., heat activated, systems and other systems currently under development, to assess their market potential, and to derive relevant proposals for desirable developments and a future International Energy Agency research and development program.

PROJECT DESCRIPTION AND STATUS: Highlights of general conclusions of the study as follows: Electric heat pumps (for both heating and cooling) predominate in the U.S.A. as replacement for boilers and furnaces. In W. Germany a similar situation exists with bivalent-alternative heating-only heat pumps.

The first priority in most countries is to substitute for oil and second, to conserve energy. Present electric heat pump types meet the first priority but rarely contribute to the second, unless compared to direct electric heating. Advanced heat pump types are capable of conserving 30% to 50% prime energy; the best systems from this aspect are internal combustion engine driven. However, in terms of oil substitution the gas fired systems are superior, i.e., Brayton, Otto and Stirling engine driven, the Rankine-Rankine and the sorption systems. External combustion systems have a total flexibility of fuel use and are thus particularly attractive, especially in large unit sizes.

Most advanced heat pumps are not due for commercialization until 1985. Thus, the possibility of achieving worthwhile energy savings before 1990 appears low. Accelerated development of the systems with greatest potential for each application is desirable, even if in the short term their use is not justifiable on economic grounds. The economic potential for all advanced heat pump systems, is limited by strong competition from conventional systems.

The overall conclusion of the study for R&D policy is relatively clear: to expand the market share for advanced heat pumps as a group, efforts should focus on advanced heat pumps most likely to generate market potential by 2000: absorption, Rankine-Rankine, and Diesel-Rankine systems. Diesel-Rankine is suited to large installations; absorption and Rankine-Rankine show greatest potential for small heating-only applications. Electric heat pumps will predominate for combined heating and air conditioning applications.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) Not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: BRAYTON-CYCLE HEAT PUMP FOR SOLVENT RECOVERY

PRIN. INVESTIGATOR: GILBERT E. LIMBERG

ORGANIZATION: AIRESEARCH MANUFACTURING COMPANY

ADDRESS: 2525 W. 190TH STREET
TORRANCE, CA 90509

TELEPHONE NO.: (213) 323-9500

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 1,293,566

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: DE-AC03-78C540005

CONTRACT AGENCY: SAN FRANCISCO OPERATIONS OFFICE

CONTRACT PERIOD:

FROM SEPTEMBER 1978 **THROUGH** MAY 1983

PROJECT OBJECTIVES: The current objectives of this program are to develop a Brayton-cycle heat pump solvent recovery system to a production-prototype level, analyze the market and business potential for adaptation to this solvent recovery system, evaluate the system first cost and actual annual performance and operating costs, and field-demonstrate a system to obtain performance/cost data and to identify problems in actual service.

PROJECT DESCRIPTION AND STATUS: The present project is the result of redirecting the development of a high-temperature electrically driven heat pump from the planned milk drying application when natural gas became more plentiful and reduced the competitiveness of the electrically driven system. The advent of the fuel oil shortage and the intrinsic value of volatile organic solvent recovery presented an attractive alternative.

The inherent cooling and heat pumping capabilities of the Brayton cycle are ideally suited to solvent recovery. It has the advantage of condensing at higher temperatures because of its higher operating pressures and the utilization of the higher temperature gas to provide heating to the solvent evaporating (oven) process.

In the application studies, it was found that the system could be used effectively and competitively in a variety of solvent recovery systems, giving it a good market penetration potential. Its market potential for 1980 was determined to be 6.3 million tons of solvent recovery out of a total of 19.3 million tons emitted to the atmosphere. Moreover, it provides industry with a means of cleaning the air; thus, in places such as California, where emission quantities are restricted, it provides for increased production.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN SOLVENT RECOVERY RATE: (LB/HR) 500 at 723,000 Btu/hr (heating)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Air/air/water

DESIGN INLET TEMP./DESIGN SOLVENT CONDENSING TEMP.: (°F) 150°/-60°

STEADY-STATE C. O. P. AT DESIGN: 0.18 (cooling); 0.75 (heating)

PROJECT SUMMARY

PROJECT TITLE: SYSTEM DEVELOPMENT STUDY OF HP-ICES BASED ON ICE MAKING HEAT PUMP USING SURFACE WATER AS A SOURCE AND SINK AND A DISTRIBUTED SYSTEM

PRIN. INVESTIGATOR: PAUL A. ANDERSON
DONALD M. CARLSON

ORGANIZATION: HONEYWELL ENERGY RESOURCES CENTER

ADDRESS: 2600 RIDGWAY PARKWAY
MINNEAPOLIS, MN 55413

TELEPHONE NO.: (612) 378-4141

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 55,166

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4845

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 9/28/78 **THROUGH** 11/30/79

PROJECT OBJECTIVES: To evaluate the feasibility of developing a heat pump centered integrated community energy system (HP-ICES) based on the use of privately owned ice making heat pumps within each building for domestic hot water, space heating, and cooling. A closed-loop water distribution system within the community is the heat source and sink: in the heating mode, users draw off water and return an ice slurry and vice versa for cooling. The energy interchange or balance among the various users is essential to this HP-ICES. A surplus of ice during the heating season is accumulated for summer cooling (this was later shown to be economically unfeasible). If either the ice surplus is not used during the summer or the ambient temperature rises above 35°F, the closed loop ice slurry system is inactivated and the heat pumps operate in the conventional air-source mode.

PROJECT DESCRIPTION AND STATUS: The concept of this particular HP-ICES was applied to a planned unit development around a shopping mall in Bloomingdale, IL. This concept suffers from the need for further technological development, impact on land use, and low initial revenues being inadequate to defray the up-front costs of the community portion of the system on a current basis. Finance charges to support early use of this HP-ICES in a growing community and additional costs of the on-site heat pump system present economic barriers that can be overcome by escalation of energy and power rates.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: Not applicable.
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: SYSTEM DEVELOPMENT STUDY OF HP-ICES USING AIR OR INDUSTRIAL-WASTE HEAT SOURCE AND A CASCADED OR DISTRIBUTED SYSTEM

PRIN. INVESTIGATOR: HAROLD G. LORSCH
RICHARD E. CRANE

ORGANIZATION: FRANKLIN RESEARCH CENTER

ADDRESS: 20th AND RACE STREETS
PHILADELPHIA, PA. 19103

TELEPHONE NO.: (215) 448-1000

SUBCONTRACTOR: (if applicable) R.G. WERDEN AND ASSOCIATES
P.O. BOX 414
JENKINTOWN, PA. 19046
215/885-2500

TOTAL FUNDING: $68,321

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: 31-109-38-4547

CONTRACT AGENCY: ARGONNE NATIONAL LABORATORY

CONTRACT PERIOD:

FROM 6/20/78 **THROUGH** 11/30/79

PROJECT OBJECTIVES: To assess the potential applications, expected performance, economics, and implementation of a heat-pump centered integrated community energy system (HP-ICES) predicated on a common piping loop from or to which users (buildings) extract or reject heat via their own water-source heat pump. A central plant maintains the water temperature in the common piping loop within a desired range. The common piping loop may be supplemented with heat from a diesel driven air source heat pump, boilers in a central plant, or waste heat from industrial sources. Cooling is accomplished by a cooling tower or pond. The HP-ICES is either cascaded or distributed depending upon whether or not a central heat pump is included.

PROJECT DESCRIPTION AND STATUS: If little or no waste heat is available from nearby industrial installations, high community energy density rates (corresponding to urban conditions) are required for economic viability of this particular HP-ICES. If large amounts of waste heat are available, even relatively loosely built up communities look promising provided the HP-ICES is owned by the municipality. For this particular HP-ICES, 16 to 32 percent less resource energy (than conventional systems) during the heating season is used; at peak heating, the savings are 37 to 51 percent. Although there is no resource energy savings for the cooling season, it saves 19 percent during the peak cooling period. Overall, the annual resource energy savings is 14 to 34 percent.

In order to demonstrate the applicability of this HP-ICES to particular sites, designs were made for Phillipsburg, NJ, and Walden, IL. Analysis concluded that conversion (retrofit) of the Heckman Terrace Public Housing Development in Phillipsburg to this HP-ICES is economically feasible compared to the existing system and in light of the availability of nearby industrial waste heat and of natural gas as a supplement. The mixed residential/commercial Walden, IL, community does not promise any savings when equipped with this HP-ICES due primarily to the low cost of natural gas in the area.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS) Not applicable

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: ANALYSIS OF ADVANCED THERMAL ENERGY STORAGE SUBSYSTEMS FOR SOLAR HEATING AND COOLING

PRIN. INVESTIGATOR: P. O'D. OFFENHARTZ

ORGANIZATION: EIC CORPORATION

ADDRESS: 55 CHAPEL STREET
NEWTON, MA 02158

TELEPHONE NO.: (617) 965-2710

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 77,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: EG-77-C-02-4483

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM SEPTEMBER 1977 **THROUGH** AUGUST 1978

PROJECT OBJECTIVES: To simulate the performance characteristics of advanced thermal energy storage subsystems for solar heating and cooling.

PROJECT DESCRIPTION AND STATUS: Four energy conditioning and storage subprograms were constructed and later integrated into a single system program that handled external variables such as solar input, environmental conditions, and heating/cooling load. This project provided two types of results: a set of programs capable of simulating the performance of a wide variety of thermal storage and conditioning units under realistic assumptions as to collector, heat exchanger, storage media, and conditioning system performance; and a set of full-year simulation runs for thermal energy storage/conditioning subsystems that have been proposed in the literature. This project was divided into the following tasks:

- Design and construction of overall system model;
- Construction of sensible, phase-change, and reversible chemical subsystem models (SPHW model);
- Electric heat pump energy conditioning with multiple storage possibilities (SAHP model);
- Absorption and Rankine-cycle air conditioning with multiple heating options and storage possibilities (TACSH model);
- Construction of model for thermal storage in thermochemically-driven heat pump (TDHP model);
- Simulation runs on published designs; and
- Additional simulation runs on the most promising designs.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT: NOT APPLICABLE
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: RESEARCH AND DEVELOPMENT OF AN AIR-CYCLE HEAT PUMP WATER HEATER

PRIN. INVESTIGATOR: William M. Toscano

ORGANIZATION: Foster Miller Associates, Inc.

ADDRESS: 350 Second Avenue
Waltham, Mass. 02154

TELEPHONE NO.: (617) 890-3200

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 381,000

SOURCE(S)	LEVEL (%)
*Department of Energy	93%
Contractor	7%

CONTRACT NO.: 7226

CONTRACT AGENCY: Oakridge National Laboratory

CONTRACT PERIOD:

FROM May 77 **THROUGH** December 79

PROJECT OBJECTIVES: The objective of this was to develop an Air-Cycle (Reverse-Brayton) heat pump water heater, analyze the market and business potential, evaluate the system first cost and actual annual performance and operating costs, and field-demonstrate a system to obtain performance/cost data and to identify problems in actual service.

PROJECT DESCRIPTION AND STATUS: A Reverse Brayton-air cycle heat pump water heater has been designed for residential application. The system consists of a compressor/expander, an air-water heat exchanger, an electric motor, a water circulation pump, a thermostat, and fluid management controls.

The advantages of a Reverse Brayton air cycle heat pump for water heating is that the system is independent of an outdoor heat exchange installation with fan, refrigeration lines, and defrosting mechanism. The electric motor and compressor/expander need not be hermetically sealed or thermally coupled, which allows each component to be optimally designed and independently maintained. The working fluid is air. The thermal load which is the sensible heat of the water is easily matched with the sensible heat of the air in the air-water counterflow heat exchanger. The coefficient of performance (COP) and heat pump capacity do not vary significantly with the ambient temperature, therefore if the system proves to be effective at standard ambient conditions, it can be considered for operation in any climate. The design goal was a COP of 1.7.

In the development program a prototype heat pump system with a COP of 1.26 was built and tested. The difference between experimental and design thermodynamic performance can be attributed to mass transfer losses and heat transfer losses. As part of the design effort, a thermodynamic parametric analysis was performed of the water heater system. It was determined that to obtain a coefficient of performance of 1.7 the isentropic efficiency of both the compressor and expander must be at least 85 percent. This program was terminated because of the low COP achieved and the development cost to achieve the target COP of 1.7.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK: Air/Air/Water

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F) $55^{o}F/140^{o}F$

STEADY-STATE C. O. P. AT DESIGN TEMP.: 1.26

PROJECT SUMMARY

PROJECT TITLE: TECHNICAL SUPPORT FOR RANKINE AND ABSORPTION SOLAR COOLING SYSTEMS PROGRAM

PRIN. INVESTIGATOR: MICHAEL WAHLIG

ORGANIZATION: LAWRENCE BERKELEY LABORAOTRY

ADDRESS: 1 Cyclotron Road
Berkeley, CA 94720

TELEPHONE NO.: (415)486-5787

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ Part of 1,372,000

SOURCE(S)	LEVEL (%)
DOE	100

CONTRACT NO.: W-7405-ENG-48

CONTRACT AGENCY: DOE

CONTRACT PERIOD:

FROM October 1976 **THROUGH** September 1986

PROJECT OBJECTIVES: Provide technical support to DOE/HQ and DOE/SAN Active Solar Cooling Development Program.

PROJECT DESCRIPTION AND STATUS:

LBL performs technical support activities for DOE/HQ and DOE/SAN in the areas of solar absorption and Rankine cooling, including technical monitoring of contracts, proposal reviews, program planning, and coordination with other organizations.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) NOT APPLICABLE

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

PROJECT SUMMARY

PROJECT TITLE: EVALUATION OF NEW AND ADD-ON HEAT PUMP TECHNOLOGY

PRIN. INVESTIGATOR: ARVO LANNUS

ORGANIZATION: GORDIAN ASSOCIATES, INC.

ADDRESS: 711 Third Avenue
New York, New York 10017

TELEPHONE NO.: (212) 697-9023

SUBCONTRACTOR: (if applicable)

TOTAL FUNDING: $ 94,000

SOURCE(S)	LEVEL (%)
DEPARTMENT OF ENERGY	100%

CONTRACT NO.: EX-76-C-01-2121
EC-77-C-03-1699

CONTRACT AGENCY: DEPARTMENT OF ENERGY

CONTRACT PERIOD:

FROM 8/19/76 **THROUGH** 1978

PROJECT OBJECTIVES: The purpose of this study was to evaluate the performance, cost and market prospects of heat pumps--both conventional and advanced-- and to assess research and development needs and make recommendations concerning Federal Government policies and support of this type of space conditioning technology. The study covered electric as well as experimental gas and other types of heat pumps and examined equipment for residential and commercial applications. Concerning the latter, unitary equipment of the type applicable to light commercial, institutional or industrial construction was investigated in preference to large built-up systems.

PROJECT DESCRIPTION AND STATUS: On-site energy consumption, energy and life cycle cost, market prospects, institutional factors and primary or resource energy efficiency of heat pumpsfor residential and commercial applications were evaluated. Only unitary equipment was considered; the investigation covered conventional electric heat pumps, experimental gas thermal engines and absorption cycle machines under development. Other heat pumps were also considered as were combinations with solar energy systems.

Calculations of the on-site and primary energy effectiveness and cost of conventional and advanced heat pumps compared to electric and combustion furnaces and baseboard heat (all with appropriate cooling systems) were made by means of two hour-by-hour computer simualtion programs -- one for a residential building, one for a commercial building. As test buildings, a two-story frame single family residence (1850 sq. ft.) and a two-story masonry office building (5580 sq. ft.) were selected. These buildings were hypothetically moved about to nine different locations (cities) selected as representative of the various climatic regions of the continental United States.

Energy costs, installed costs and life-cycle owning and operating costs were determined for the residential and commercial HVAC systems. Energy costs were based on locally obtaining utility rates, accounting for base load usage and demand charges, where appropriate. Installation costs were based on an estimate including labor, materials, shipping, handling and taxes. Life cycle costs were calculated assuming an 8% annual inflation in energy costs and a lower rate of inflation in maintenance costs.

Models of the residential and non-residential building market were used to project market penetrations of heat pumps. The models account for replacements and conversions as well as new construction. Market projections were combined with primary energy consumption results to estimate potential energy savings from advanced electric and gas heat pumps. The study also considered institutional factors such as consumer attitudes, building codes, gas availability and other pertinent factors.

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR)

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

Not applicable

PROJECT SUMMARY

PROJECT TITLE: DEVELOPMENT OF PERFORMANCE EVALUATION PROCEDURES FOR HEAT PUMPS

PRIN. INVESTIGATOR: David A. Didion

ORGANIZATION: National Bureau of Standards

ADDRESS: Room B128, Bldg. 226
National Bureau of Standards
Washington, D.C. 20234

TELEPHONE NO.: (301) 921-2994

SUBCONTRACTOR:
(if applicable)

TOTAL FUNDING: $ 2,000,000 (approx.)

SOURCE(S)	LEVEL (%)
Department of Energy	80%
Oak Ridge National Laboratory	10%
National Bureau of Standards	10%

CONTRACT NO.: Interagency Agreement

CONTRACT AGENCY: Department of Energy

CONTRACT PERIOD:

FROM 1975 **THROUGH** Present

PROJECT OBJECTIVES:

The overall objective of this program has been to develop performance evaluation procedures for the rating of heat pumps of various designs (< 10 ton capacity). Emphasis has been on laboratory testing and seasonal efficiency rating methodology for the typical electric motor driven compressor type currently used in residences. Advance concept heat pump (e.g., multi-speed, hybrid, engine driven, absorption) methodologies have also been designated for study as well.

PROJECT DESCRIPTION AND STATUS:

Since 1975 NBS had had a continually active applied research program in the general area of heat pump energy performance. In keeping with the NBS mission the program has been primarily laboratory oriented and focused on problems of performance measurement and evaluation; although, the completeness of such studies has required a variety of theoretical studies as well as field evaluation projects, for support. The results of much of this work led to the test and rating procedures that are currently being used by the industry for their efficiency labeling requirements. Modifications to these procedures has been a continuing process as more testing experience is gained by more industrial labs and as more different heat pump designs appear in the marketplace. In addition to this work on conventional heat pumps, several evaluation studies and procedures for innovative systems have been conducted for the purpose of assisting in determining their energy performance potential. In FY81, the five heat pump projects that are currently being worked on (at various stages of development) are:

1. Steady-State Heat Pump Model
2. Transient Heat Pump Model
3. A Study on the Rating of Mix-Match Indoor/Outdoor Units
4. A Residential Heat Pump Field Monitoring Study
5. A Study of the Dynamic Performance of an Absorption Water Chiller

HEAT PUMP DESIGN SPECIFICATIONS OF EVENTUAL PRODUCT:
(FOR HARDWARE DEVELOPMENT PROJECTS)

DESIGN THERMAL OUTPUT OF HEAT PUMP: (BTU/HR) not applicable

WORKING FLUID/HEAT SOURCE/HEAT SINK:

DESIGN COND. TEMP./DESIGN EVAP. TEMP.: (°F)

STEADY-STATE C. O. P. AT DESIGN TEMP.:

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APPENDIX A

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This report contains projects which deal with building services (space heating, cooling and water heating) and with industrial applications. Since the vast majority of projects deal with the buildings applications, this appendix provides a means of quickly locating industrial-oriented projects. Included in the projects listed below are (1) projects which have a specific (and usually sole) application to industrial uses and (2) a few building service projects whose technology has a strong potential use in industrial applications.

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Over eighty percent (80%) of the projects in this report are sponsored wholly or partly by the U.S. Department of Energy (DOE). The remaining projects are initiated and funded by the sponsoring organizations listed in section 3 of this report. To provide an overview of the heat pump programs of these organizations and to provide easier access to individual projects which they sponsor, this appendix presents a list of projects for which a non-DOE organization is the prime sponsor (i.e. the organization who is listed as the contract agency on the project summary form). Also included are several projects for which DOE and the Gas Research Institute share funding equally.

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