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COLORADO STATE UNIVERSITY PROGRAM FOR
DEVELOPING, TESTING, EVALUATING AND OPTIMIZING
SOLAR HEATING AND COOLING SYSTEMS

PROJECT STATUS REPORT FOR THE MONTHS OF
SEPTEMBER AND OCTOBER 1991

Prepared for the

U.S. Department of Energy
Conservation and Solar Applications
Under Grant DE-FG03-86-SF16306

Submitted by

Solar Energy Applications Laboratory
Colorado State University

November, 1991

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November 22, 1991

Report No: SF-16306-31

Report Period: 1 September, 1991 to 31 October, 1991

PROJECT TITLE:

Developing, Testing, Evaluating and Optimizing Solar Heating and Cooling Systems

GRANT NUMBER: DE-FG03-86-SF16306

GRANTEE NAME: Solar Energy Applications Laboratory
Colorado State University
Fort Collins, Colorado 80523

GRANT PERIOD: 1 June 1986 to 29 February 1992

GENERAL STATUS:

1. Project Objective:

The objective is to develop and test various integrated solar heating, cooling and domestic hot water systems, and to evaluate their performance.

2. Technical Approach:

Systems composed of new, as well as previously tested, components are carefully integrated so that effects of new components on system performance can be clearly delineated. The SEAL-DOE program includes six tasks which have received funding for the 1991-92 fifteen-month period. These include: (1) a project employing isothermal operation of air and liquid solar space heating systems, (2) a project to build and test several generic solar water heaters, (3) a project that will evaluate advanced solar domestic hot water components and concepts and integrate them into solar domestic hot water systems, (4) a liquid desiccant cooling system development project, (5) a project that will perform system modeling and analysis work on solid desiccant cooling systems research, and (6) a management task. The objectives and progress in each task are described in this report.

3. Project Tasks:

SOLAR HEATING WITH ISOTHERMAL COLLECTOR OPERATION AND ADVANCED CONTROL STRATEGY

Status: Activity during September and October was devoted to finalizing the simulation (TRNSYS) studies on constant temperature and constant flow solar heating. Particular attention was given to the pumping power analysis and to the effects of storage tank size on overall system performance (seasonal solar fraction).

GENERIC SOLAR DOMESTIC WATER HEATING SYSTEMS

Status: Twelve experimental trials of the generic anti-freeze system are completed. The design of the solar simulator is in its final stages of development. The light source for the simulator consists of twenty-eight 1000-Watt Compact Source Iodine (CSI) lamps arranged in an array of four by seven bulbs. Using multiple lights, the primary design problem is to uniformly irradiate the collector surface. This is achieved by a combination of varying the output of the lamps and the use of a highly reflective collimator placed in front of each bulb.

A biaxially indexed matrix of incidence angle modifiers for the NEG integral collector storage DHW system has been generated by the Colorado State University solid modeling three dimensional ray trace program.

ADVANCED DOMESTIC HOT WATER (DHW) SYSTEMS

Status: Primary short-term project emphasis is being placed on matched flow DHW systems and longer term emphasis is on integral collector storage systems. A matched flow system is defined as a SDHW system where collector flow allows the storage to be stratified optimally in regard to the load and storage volume. Other SDHW systems that are being examined are the passively vented American Solar Network system and the Copper Cricket.

Modeling is currently being carried out on one- and two-tank versions of five SDHW systems. Optimized designs of these systems will be experimentally evaluated in the next contract period beginning March 1992.

LIQUID DESICCANT COOLING SYSTEM DEVELOPMENT

Status: Structured packing (Munters CELDEK) was installed in the dehumidifier with the bed height of 1 foot. Condensation rate studies were carried out for this structured packing in the manner similar to that of the random packing. The slope of the graph of condensation rate versus the solution flow rate was found to be 0.84. The Wilson's plot obtained from this graph was found to be a straight line with intercept 0.014. This small value of the intercept suggests that the gas phase mass transfer resistance was again negligible and the Lewis number was greater than 1, unlike that for the air/water operations. However, the condensation rates obtained for this packing were significantly lower than those for the random packing.

Evaporation rate studies were carried out for the random packing in the regenerator. The plot of evaporation rate versus the solution flow rate was found to be a straight line with slope 0.82. This value of the slope suggested that the regenerator was operated under well-mixed, nearly turbulent conditions for liquid flow, as was the case for the dehumidifier. The small value of the intercept (0.015) obtained from the Wilson's plot

suggested that the gas phase mass transfer resistance was negligible and the Lewis number for these contact operations would be greater than 1 unlike that for air/water operations. Thus, the mass transfer resistance for the air/solution contact in the regenerator resided primarily in the liquid, as was found for the dehumidifier.

ANALYSIS OF ADVANCED SOLID DESICCANT SOLAR COOLING SYSTEMS

Status: Activities began on the solar cooling task in September immediately upon approval of the project by DOE. Analyses of SENC and other high performance desiccant cooling cycles are being planned. TRNSYS components are being developed in coordination with previous work at the University of Wisconsin to compare performance of the cycles and to verify that the design parameters are consistent with reasonable economic and size limitations. Two of the best performing cycles will be selected for further optimization and for simulation in three U.S. sites with high population and cooling demand.

MANAGEMENT AND COORDINATION OF COLORADO STATE/DOE PROGRAM

Status: Coordination of research activities continued on the five research tasks under the DOE grant, and accounts were maintained and updated. Initial financial planning reports and bimonthly financial and technical reports were submitted.

SOLAR HEATING WITH ISOTHERMAL COLLECTOR OPERATION AND ADVANCED CONTROL STRATEGY

Research Team:

Charles C. Smith, Task Leader
George O.G. Löf, Senior Advisor
Douglas C. Hittle, Advisor
Ihsan A. Abbud, Graduate Research Assistant

Objectives:

As principally a systems performance laboratory, an objective in recent years at the Colorado State University Solar House I has been to increase overall system performance at negligible added cost. This effort has proven most successful in the areas of improved control strategy and temperature stratification in the water storage tank. Seasonal system efficiency, the ratio of useful energy to space heating divided by solar energy on the collector surface, increased from 36 to 50 percent. Or, in economic terms, the value added to the system is 39 percent without appreciable cost increase.

While increased system efficiencies continues to be an important objective of this task, it is recognized that other factors are critical to owner acceptance of solar heating. Comfort, convenience, and physical compactness of systems are equally important and shall be addressed in the project.

A companion objective is the improvement of indoor air quality by use of increased ventilation levels to the space while it is heated. Awareness of radon, formaldehyde, and other pollutants within tightly constructed buildings has brought this matter to a new importance.

The principal objectives of the 1991 solar heating project are to develop control options and to model the use of flat plate collectors and dual temperature zone, single tank storage for isothermal operation.

Work Plan:

1. Model the effects of employing commercial type flat plate collectors in isothermal operation under different load patterns and solar availability.

It is proposed to model the performance of flat plate collectors under isothermal operation. The flat plate collector will respond somewhat differently to isothermal control due to greater environmental sensitivity of flat plates compared with the presently employed evacuated tube type. We expect that isothermal control will benefit flat plate systems even more than evacuated tube systems.

2. Model the effects of a single storage volume capable of maintaining two temperature zones of 25 C (or greater) difference.

The use of a single, but highly stratified, storage unit will be modelled. This will be performed in order to specify the best

design, geometry, or configuration such as multiple smaller tanks in series.

3. Simulate and assess the use of solar (radiation) sensor controlled collector pump as a means of approximate isothermal collector operation without temperature feedback control.

Perfecting this control strategy could simplify the hardware and/or permit the use of a PV-powered pump.

4. Identify motor/pump units which will provide variable volume flow efficiently and economically.

Under this effort, we will collaborate with motor and pump manufacturers to select or develop an appropriate variable speed pumping system for typical solar heating systems.

5. Introduce advanced control strategies to control collector loop flow.

The present system will be operated with a newly installed PC computer data acquisition/control system. This system will be used to test the best strategies for pump control for isothermal operation. Problems associated with pump start-up for the drainback system need to be resolved and tuning criteria need to be developed.

Progress:

Activity during September and October was devoted to finalizing the simulation (TRNSYS) studies on constant temperature and constant flow solar heating. Particular attention was given to the pumping power analysis and to the effects of storage tank size on overall system performance (seasonal solar fraction).

A significant factor in the evaluation of collector pumping power is the determination of the power required in a typical solar collector installation. The efficiency of the motor/pump assembly over the expected flow rate range is an essential component of the analysis. Experience at the Colorado State Solar Energy Applications Laboratory, as well as the references of others, has provided the necessary information for a pump power computation in the TRNSYS model.

The effect of the energy storage tank size, relative to collector area, was also investigated. Figure 1 shows typical results for both the constant temperature and constant flow conditions. The figure indicates that the solar fraction is not strongly affected by storage tank size above 75 liters per square meter collector area. (Typical solar heating installations average 100 liters per square meter.) Thus, 75 liters per square meter has been taken as the storage volume for all simulations.

Figure 1

GENERIC SOLAR DOMESTIC WATER HEATING SYSTEMS

Research Team:

Jane H. Davidson, Task Leader
William S. Duff, Co-Task Leader
Mark Thornbloom, Graduate Research Assistant
Steve Kenny, Graduate Research Assistant

Objectives:

Certification of any solar domestic hot water (DHW) system by the Solar Rating and Certification Corporation (SRCC) currently requires an extensive laboratory system test in addition to the collector test. This procedure places a significant economic burden on a low sales volume industry and reduces the overall cost competitiveness of solar DHW versus gas and electric systems.

A research program supported by the Department of Energy to investigate the feasibility of a more cost effective rating method for solar DHW systems is now in progress at the Solar Energy Applications Laboratory (SEAL) at Colorado State University in conjunction with the University of Wisconsin, Solar Energy Research Institute (SERI) and SRCC. The main thrust of the research is to determine if ratings of solar DHW systems can be accurately based on computer simulations. The immediate goal is to determine if the simulation program, TRNSYS, can accurately predict the performance of drain-back, recirculation, anti-freeze, thermosiphon and internal collector storage solar DHW systems.

Work Plan:

1. Experimental study of the anti-freeze system is currently underway and results will be presented in July at a group meeting to be held in Washington, D.C. Study will focus on heat exchanger design and operation and system flow rates.
2. The single test of the recirculation system will be completed later in the summer. This delay is due to an agreement by project participants that additional study of flow rates in the anti-freeze system are needed.
3. A generic systems program for thermosiphon and internal collector storage (ICS) SDHW systems will be initiated. Colorado State, in cooperation with SRCC, representatives from the U.S. solar industry, SERI, and University of Wisconsin, will develop and carry out an experimental study of these systems. A solar simulator will be added to current outdoor testing facilities at SEAL to accomplish this phase of the project.
4. Thermosiphon system performance will be investigated for a system using a wrap-around heat exchanger. Stratification in horizontal tanks will also be explored. It is expected that the thermosiphon work will be completed during this project period.
5. Study of the ICS system will focus on determining if an analytical ray trace can be used to accurately predict incidence angle modifiers

for three complex geometries (tube storage tank in a "bread box", tube storage tank with parabolic shaped collector, and tube storage tank in a tubular collector). The ICS experimental results will be completed in the 1992 budget period.

6. Additional efforts in the 1992 budget period include validation of an analytical approach for predicting performance of non-generic DHW systems such as the Copper Cricket.

Progress:

The design of the solar simulator is in its final stages of development. The light source for the simulator consists of twenty-eight 1000-Watt Compact Source Iodine (CSI) lamps arranged in an array of four by seven bulbs. Using multiple lights, the primary design problem is to uniformly irradiate the collector surface. This is achieved by a combination of varying the output of the lamps and the use of a highly reflective collimator placed in front of each bulb. Comparison of irradiance contour plots with and without the collimator shows that the use of even a simple box design focuses light over nearly a 13 percent smaller area with a corresponding increase in average irradiance. The final multiple bulb arrangement is based on radiation flux measurements from a single bulb. Contour maps of the multiple bulb array are determined by overlaying the data to simulate a full-scale system. These simulations are in progress. The contour plot of Figure 2 shows an overlay with nine bulbs at a constant power level of 1 kW. By increasing power to the edge of the array, and decreasing power in the center, an optimal, uniform array pattern will be established.

All twelve experimental rating trials of the generic antifreeze system are completed. Results of the trials are shown in Table 1.

Two papers on the generic systems work have been submitted to the ASSES meeting to be held in Cocoa Beach in June, 1992.

A biaxially indexed matrix of incidence angle modifiers for the NEG integral collector storage DHW system has been generated by the Colorado State University solid modeling three dimensional ray trace program.

Figure 2 —Irradiance contour p'ot of an overlay of nine bulbs 50 cm apart at a distance of 295 cm from the test plane. The power meter setting is 1 kW with a measurement grid spacing of 5.56 cm.

Table 1

Summary of Experimental Results

Trial	Heat Ex-changer Type	Collector Flow Rate [l/s]	Recirc-ulation Flow Rate [l/s]	SF [%]	Q _{del} [kJ]	Q _s [kJ]	Q _{net} [kJ]	Q _{res} [kJ]	Q _{aux} [kJ]	Q _{par} [kJ]	Q _u [kJ]
1	1	0.114	0.170	41.24	49810	24829	20540	17978	29941	4289	31068
2	1	0.114	0.085	39.58	49810	23950	19714	17285	30560	4236	30042
3	1	0.228	0.170	44.27	49812	26466	22052	19600	28729	4415	31199
4	1	0.228	0.085	41.69	49815	25165	20769	18222	29715	4396	29710
5	2	0.114	0.170	36.16	49811	24329	18013	18549	31813	6316	29326
6	2	0.114	0.085	42.03	49814	25235	20937	17989	29842	4298	30642
7	2	0.228	0.170	37.82	49819	25489	18843	19101	30141	6646	29967
8	2	0.228	0.085	34.64	49812	23582	17257	18080	31835	6325	29863
9	1*	0.114	0.176	33.24	49812	20869	16558	16145	34275	4312	28086
10	1*	0.114	0.095	33.76	49811	21105	16817	15779	33777	4288	27842
11	1	0.057	0.043	35.52	49812	22116	17693	15214	32650	4423	31780
12	2	0.057	0.043	36.06	49810	22379	17964	15079	32621	4416	28509

* Inverted Heat Exchanger: Inlets are at the bottom

ADVANCED SOLAR DOMESTIC HOT WATER (DHW) SYSTEMS

Research Team: William S. Duff, Task Leader
Jane H. Davidson, Co-Task Director
Ron Hill, Graduate Research Assistant

Objectives:

In the next few years, a renewed United States mass market for residential solar DHW systems is expected to develop as heightened environmental concerns spawn legislation and other incentives for alternative energies and energy conservation. This market will be accessible to products from other countries that are currently being developed with substantial research and development support from their governments. For United States manufactured solar DHW systems to remain competitive, cost effective solar DHW systems employing advanced materials, components, and concepts must be developed.

A research project funded by the Department of Energy to identify, analyze, design, build, and experimentally evaluate such solar DHW systems is currently underway at the Colorado State University Solar Energy Applications Laboratory. The objective of this project is to substantially lower costs and improve performance of commercial solar DHW systems in the United States. Several United States manufactured solar DHW systems with desirable features will be chosen as starting points for the design improvement process. As a means of identifying many promising materials, components, and concepts, this project is participating as the United States solar DHW installation in the International Energy Agency Task on Advanced Solar Energy Systems. Results from this project, as well as results from the International Energy Agency activities, will be disseminated to the United States solar energy industry.

Work Plan:

- 1) Represent the United States DOE as the United States Advanced DHW project leader in IEA Task XIV. This activity includes preparing reports on the United States single-pass and internal collector storage DHW systems work and discussing this and other United States solar DHW work at the meetings.
- 2) Represent the United States DOE as the leader of the IEA Task XIV working group. This activity includes preparing for and leading the working group meetings, summarizing the results, preparing the working group work plans, reminding participating countries of their deadlines, and working with the Task XIV Operating Agent to insure that working group goals are met. (In a later contract period this activity will include writing a Task XIV Advanced DHW Systems report.)
- 3) Report other information to working group participants as may be necessary.
- 4) Simulate the behavior of single-pass solar DHW system variable flow and radiation switch controllers. Study the effects of stratification and stratification enhancing devices. Develop a systems simulation for the single-pass DHW and baseline systems that incorporates component models developed by us, SERI, and other participating IEA countries. Develop an optimum design for the single-pass system based

on cost, performance and reliability. Prepare a plan for building and testing this system.

- 5) Assemble and integrate the Colorado State University Generic Systems incident angle modifier studies and other work for the Internal Collector Storage systems into IEA Task XIV activities.
- 6) Communicate the results and planned activities of the Colorado State University Advanced DHW task to the United States solar industry.

Progress:

This project is being conducted in conjunction with the International Energy Agency Solar Heating and Cooling Program's Task XIV on Advanced Active Solar Energy Systems. Modeling, design, experimentation, and analyses conducted by this project provides the United States SDHW contribution to Task XIV. Additionally, Professor Duff is the leader of the advanced SDHW systems activities of Task XIV.

Primary short-term project emphasis is being placed on matched flow DHW systems and longer term emphasis is on integrated collector storage systems. A matched flow system is defined as a SDHW system where collector flow allows the storage to be stratified optimally in regard to the load and storage volume. Other SDHW systems that are being examined are the passively vented American Solar Network system and the Copper Cricket.

Modeling is currently being carried out on one- and two-tank versions of five SDHW systems:

- 1) A baseline "most representative" United States system.
- 2) A variable flow control strategy system.
- 3) A low-flow system with stratification manifold.
- 4) A low-flow system with a stratification enhancing internal heat exchanger.
- 5) The passively vented collector American Solar Network system.

Optimized designs of these systems will be experimentally evaluated in the next contract period beginning March 1992.

Several variations of the American Solar Network collector have been modeled, including a low-flow version, with very positive results.

A small diameter ethylene propylene piping material for use in the matched flow system is being investigated.

An internal heat exchanger design that promotes tank stratification is currently being modeled.

A biaxially indexed matrix of incidence angle modifiers for the NEG integral collector storage DHW system has been generated by the Colorado State University solid modeling, three-dimensional, ray trace program.

An initial IEA Task XIV project work plan on integral collector storage systems and an updated work plan on matched flow systems was written and distributed to Task XIV participants.

This project was begun in the 1990 contract period at an initially low level of funding. It is DOE's expectation that funding will increase for this project in the Colorado State University contract beginning March 1, 1992. We are currently operating at a staffing level less than one-quarter of that required.

LIQUID DESICCANT COOLING SYSTEM DEVELOPMENT

Research Team: Terry G. Lenz, Task Leader
Shailesh Potnis, Graduate Research Assistant

Objectives:

Primary objectives of this project include the development, testing, and performance evaluation for a liquid desiccant cooling system on Solar House II at Colorado State. Our existing experimental cooling system comprises solar collectors, two simple packed-bed contactors (a dehumidifier and a regenerator), heat exchangers, blowers, pumps, air pre-conditioning equipment, and data-acquisition hardware, as shown on the accompanying schematic diagram.

Work Plan:

1. Determine the characteristic mass transfer dimension for our Tripak random packing.
2. Obtain water diffusivity data for concentrated liquid desiccant solutions.
3. Carry out further mass transfer studies on the dehumidifier to complete the reciprocal coefficient analysis for random Tripak packing and structured Munters packing.
4. Conduct detailed mass transfer studies on the regenerator, analogous to those carried out on the dehumidifier, to assess the relative resistance to mass transfer for the gas and liquid films.
5. Provide bi-monthly progress reports and a final technical report covering our liquid desiccant system work.

Progress:

Structured packing (Munters CELDEK) was installed in the dehumidifier and the bed height was maintained at 1 ft (30 cm) to match the bed height of the random packing used earlier. As the pieces of packing were cut to provide a tight fit, it was not necessary to use glue or wire to keep them together. This arrangement eliminated the problems of contamination of the solution due to the glue and interference in the flow due to the wires.

Condensation rate studies are being carried out for this structured packing in the manner similar to that of the random packing. Using the same set of equations, the plot of condensation rate versus the solution flow rate is obtained. The slope of the graph is found to be 0.84 (Figure 3), which is very close to the value obtained for the random packing (0.8). However, the condensation rates obtained for this packing are significantly lower (approximately half) than those for the random packing.

The Wilson's plot obtained from this graph is found to be a straight line with intercept 0.014 (Figure 4). This small value of the intercept suggests that the gas phase mass transfer resistance is again negligible and the Lewis number is greater than 1, unlike that for the air/water operations.

Fig.3 Variation of condensation rate
for structured packings.

Fig.4 Wilson's plot for structured packings in the dehumidifier.

The rate of evaporation in the regenerator depends on various parameters such as air flow rate, solution flow rate, solution concentration, air and solution inlet temperatures, and the height of the packed bed. All these parameters, except the solution flow rate, are maintained constant in the decoupled runs to study the variation of evaporation rate with the solution flow rate. The enthalpy change in solution due to latent heat of evaporation can be obtained from the sensible heat changes in air and solution.

$$\Delta H_{\text{evap}} = \Delta H_a - \Delta H_s \quad [1]$$

where,

$$\begin{aligned} \Delta H_{\text{evap}} &= \text{latent heat change due to evaporation} \\ \Delta H_a &= \text{sensible heat change in air} \\ \Delta H_s &= \text{sensible heat change in solution.} \end{aligned}$$

The mass of water evaporated per unit time can be obtained from

$$M_{\text{evap}} = \Delta H_{\text{evap}} / H_v \quad [2]$$

The plot of evaporation rate versus the solution flow rate is constructed to represent the conventional plot of Sherwood number versus Reynolds number. Figure 5 shows that this plot is a straight line with a slope of 0.82 (R^2 of 0.94). This value of the slope suggests that the regenerator is operated under well-mixed, nearly turbulent conditions for liquid flow, as was the case for the dehumidifier. The Wilson's plot constructed using this value of the slope (Figure 6) is found to be a straight line with intercept 0.015. The small value of the intercept suggests that the gas phase mass transfer resistance is negligible and the Lewis number for these contact operations will be greater than 1 unlike that for air/water operations. Thus, the mass transfer resistance for the air/solution contact in the regenerator resides primarily in the liquid, as was found for the dehumidifier.

New valves were installed in the pipelines connecting the cooling tower to the rest of the apparatus to facilitate easy draining. A direct connection was also made between the tap water line and these pipelines. These modifications were done to reduce the priming time for the water pump and take advantage of sunny winter days.

The necessary maintenance tests, specifically the pH tests and the chromate tests, were also carried out regularly during this period.

Fig.5 Variation of evaporation rate for random packings

Fig.6 Wilson's plot for random packings
in the regenerator.

ANALYSIS OF ADVANCED SOLID DESICCANT SOLAR COOLING SYSTEMS

Research Team:

Charles C. Smith, Task Leader
George O.G. Löf, Senior Advisor
Douglas C. Hittle, Advisor
Ihsan A. Abbud, Graduate Research Assistant

Objectives:

Research on solar cooling with solid desiccant systems began with the ASK Energymaster unit in the summer of 1987. The first system employed a process known as the Pennington cycle. All of the conditioned air for cooling was supplied from the outside. It was dehumidified, and cooled by heat exchanger, then by evaporative cooling. This cycle exhibited the expected cooling capacity for the unit (3 tons), and a COP of 1.0. The following year an advanced cycle (SENC) was introduced which provides sensible cooling in the recirculated house air duct and yields a higher COP. The COP increased to approximately 1.5; however the capacity dropped substantially to the range of 1.0 to 1.5 tons.

The 1988 experiments were aimed primarily at increasing the capacity of the SENC cycle. The best available commercial cooling tower was not suited for this application. It provided too little residence time for the cooling water and wasted much of the dehumidifying effect provided by the ASK. The cooling tower was rebuilt with new packing, improved water distribution, and provisions for greater air and water flow adjustments. The duct cooling coil was also increased in size by fifty percent to better match the increased cooling tower capacity. Although these changes resulted in some improvement in the cooling capacity, the desired 3-ton target was not reached.

During 1989, important information was generated from an analysis based upon the tests of previous years. The analysis employed a TRNSYS computer model with values of specific engineering parameters based on the actual equipment used in the experiments. This work revealed that some earlier modeling used unrealistic performance values for components and thus explained partially the shortfall in experimental performance. Most important, the analysis revealed some improvement recommendations which involve adjustments in air flow, cooling water flow, and desiccant wheel speed. It was also shown that the cooling capacity could be significantly increased with modest increases in regeneration temperature. A major item identified in this study was a shortfall in the experimental cooling tower capacity.

In August of 1990 a meeting of Colorado State, ASK, and Texas A&M experts was held to review the status of the solid desiccant cooling project and offer recommendations for its future course. The findings of the Colorado State analysis were confirmed by this group. Evaluation of the results showed, moreover, that the desiccant wheel had not been dehumidifying up to specifications, and that there had been physical loss of the desiccant material itself. The desiccant wheel was resupplied with the proper quantity of lithium chloride.

Wheel speed and air flow adjustments were also performed. These improvements were tested for short periods and only with respect to ASK unit

performance (not the overall system performance), due to limited time and funding. These tests indicated that significant improvement in overall cycle performance is possible, both for the Pennington and SENC processes.

Work Plan:

The primary objective of the solid desiccant cooling project is to analyze and model the advanced, high efficiency cooling cycle based upon recent and increased knowledge of potential improvements. Specific tasks to be accomplished in this grant period include:

1. Summarize existing simulation and experimental results in a form and format to assist DOE program managers in the continued refinement of the solar desiccant cooling program.
2. Use TRNSYS to simulate the SENC solar cooling cycles using improved desiccant and heat wheel models (with the TRNSYS 13.1 and later versions).
3. Simulate and analyze the SENC cycle with separation of the process and building air streams through the cooling coil.

This modification has been reported as the CHILLC cycle, but with no performance information. By separating the process and building air streams at the cooling coil, two advantages are realized. A second law performance penalty is avoided by preventing the mixing of two streams of air at different psychometric conditions. Secondly, the process air flow rate can be optimized independently of the building air flow rate.

4. Simulate and analyze the SENC cycle with building return air used as supply air to the dehumidifier.

Another variation to the present SENC cycle which needs to be analyzed is one in which the building return air is used as supply air to the dehumidifier. One advantage of using the building return air is to again increase the air flow rate through the desiccant and heat exchanger elements of the system. A second advantage is that this air usually has lower humidity. Lower humidity conditions would not prevail at all times, and thus modeling of the overall performance is needed.

Progress:

Activities began on the solar cooling task in September immediately upon approval of the project by DOE.

Analyses of SENC and other high performance desiccant cooling cycles are being planned. Table 2 contains a listing of desiccant cooling cycles which are under investigation, as well as one other proposed earlier by the Colorado State project personnel. TRNSYS components are being developed in coordination with previous work at the University of Wisconsin to compare performance of the cycles and to verify that the design parameters are consistent with reasonable economic and size limitations.

Table 2. Desiccant Cooling Cycle COP Values

Cycles	Investigators	Thermal COP
Pennington	Schlepp and Barlow	1.2
	Crum, Mitchell, Beckman	0.77
	Grolmes, Epstein	1.4
	Exxon Tests	1.1
	Colorado State Tests	0.78
	Majundar, Worek, Lavan	0.5
	MacLaine-Cross, Kang	1.04
Recirculation	Jurinak, Mitchell, Beckman	0.5 - 0.78
	Majundar, Worek, Lavan	0.7
SENS	MacLaine-Cross, Kang	2.58
	Crum, Mitchell, Beckman	2.08
SENS (Recirc Mode)	Crum, Mitchell, Beckman	2.91
SENC	MacLaine-Cross, Kang	2.41
IEC	Crum, Mitchell, Beckman	0.96
IEC (Recirc Mode)	Crum, Mitchell, Beckman	1.17
DINC	Waugaman, Kettleborough	1.1 - 1.93

Two of the best performing cycles will be selected for further optimization and for simulation in three U.S. sites with high population and cooling demand.

The recent investigations of Waugaman (1991) as well as the monitoring experience at Colorado State, point out the significance of electrical requirements of fans supplying air for cooling and air for desiccant regeneration. The study will include the electric energy requirements of the cooling cycles.

MANAGEMENT AND COORDINATION OF COLORADO STATE/DOE PROGRAM

Research Team: Douglas C. Hittle, Director
George O.G. Löf, Senior Advisor
Janice M. Stapleman, Administrative Assistant

Objectives:

Coordinate SEAL-DOE task efforts, provide assistance to DOE, and attend programmatic meetings as requested by DOE.

Work Plan:

1. Collaborate with leaders of the five technical tasks in coordination of SEAL program.
2. Organize team and sub-team planning sessions necessary for the conduct of the tasks.
3. Provide and manage necessary facilities and services to leaders and personnel involved in each task.
4. Provide timely bimonthly reports on all tasks as required by contract.
5. Maintain fiscal control of program.
6. Attend meetings and technical reporting sessions as requested by DOE.
7. Assist DOE in developing multi-year program plans.
8. Respond to DOE requests for information on solar equipment and its operation, for review of reports, and for panel and committee participation.
9. Provide technical consultation from director and senior advisor to task leaders and research personnel.

Progress:

The grant renewal for the contract period December 1, 1990 through February 29, 1992, was received at Colorado State University's Office of Sponsored Programs on September 9, 1991. Until that time, from December 1, 1990 through September 8, 1991, Colorado State University carried all expenses of the SEAL-DOE research projects. An amendment to the grant for an additional \$10,000 capital equipment funds for the Generic Systems work was received in the Office of Sponsored Programs on October 2, 1991, bringing the total of DOE's portion of the grant to \$435,000.

Coordination of research activities continued on the five research tasks under the DOE grant, and accounts were maintained and updated. Initial financial planning reports and bimonthly financial and technical reports were submitted.

END

**DATE
FILMED**

01 / 23 / 92