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Proceedings of
The U.S. Department of Energy's Regional Solar Updates 1979

Volume Two: Invited Papers and Appendices

Four Regional Conferences Highlighting the Experiences of the National Commercial and Residential Solar Heating and Cooling Demonstration Program and the National Solar Data Program

July-August 1979

Dearborn, Michigan; Orlando, Florida; Philadelphia, Pennsylvania; Los Angeles, California

Sponsored by:
U.S. Department of Energy
In Cooperation with:
U.S. Department of Housing and Urban Development
and Solar Energy Research Institute

MASTER

Hosted by:
Northeast Solar Energy Center
Mid-American Solar Energy Complex
Southern Solar Energy Center
Western SUN

Prepared for:
U.S. Department of Energy
Assistant Secretary for Conservation and Solar Energy
Office of Solar Applications

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Under Subcontract XI-9-8153-1

Coordinated by:
'RC Energy Analysis Company
.rinity University

INVITED PAPERS

DEARBORN, MICHIGAN

Solar Works--It Works Now

Dr. Donald E. Anderson
Director
Mid-American Solar Energy Complex

During the course of this Solar Update conference, we are going to be hearing descriptions of projects that amount to being "solar successes." Some have involved setbacks or difficulties, of course, and you'll be hearing about those, but in the main they have been representative of solar applications that work...now. There are those who, for various reasons, like to depict the pursuit of solar energy as a kind of warm, romantic adventure that may make the pursuers feel good, but doesn't bear much relationship to reality. For those of us who are still burdened with solar inferiority complexes... it's time to drop them. What reasoned individual, after all, can still argue that solar is within the exclusive purview of Buck Rogers? It no longer serves anybody's purpose to be negative about this or any other alternative energy form. None of us think that solar can supply 100% of our energy needs in the foreseeable future, even if we curb our voracious national appetite for fuel. But it can provide an important portion of the alternative energy mix that we must develop if future generations are not to be subjected to a significantly diminished quality of life from the one to which we have become accustomed.

The story is told that Thomas A. Edison sunk a good deal of the income which his corporation had earned from the phonograph and moving pictures in attempting to develop the electric light bulb. At an annual meeting of his corporation a disgruntled stockholder asked him to describe what they had done with all the research and development expenditures. "We now know," Edison replied, "10,000 ways <u>not</u> to make a light bulb!"

The rest is history--a way was found which <u>did</u> work, and the electrical industry was spawned by that demonstration. There is a parallel in this story which I propose to apply now to the emerging solar industry. The question is "Does solar energy have the capability of providing a meaningful contribution to our energy needs in the near term, with acceptable cost, reliability, and energy efficiency?"

The message is that, once one successful application can be found, there is no virtue in describing even 10,000 ways which did <u>not</u> work. Solar works--it works <u>now</u>--and it will evolve in the future into a major industry. Such applications can be found and cited, not once, but hundreds of times!

Solar energy is not "all things for all applications" today, nor is it likely to be in the near future. There <u>is</u> virtue in examining both successes and failures as giving guidance. From the successes, we can determine what works best for a given application and whether that best is good enough. From the failures, we also learn; what to avoid in trying new things, what to look for in making intelligent decisions "to buy or not to buy."

Those of us from within the Mid-American Region are well acquainted with the task facing us. Climatological conditions are sufficiently intense and our energy production sufficiently miniscule so that the rest of the nation could temporarily enjoy an energy surplus by ceding us to Canada if it could fathom a way to feed itself thereafter.

The people you are going to be hearing from have proven that there are alternatives to strengthening the rest of the world's currency and that they have immediate applicability. The public doesn't need convincing; they are telling us that they want a measure of economic self-determinism. They are questioning just how much of their disposable income it is worth just to keep their homes warm in the winter months.

The people who do need convincing include those in the lending, appraising, and educational sectors. The peers of some of us here today, whether they be engineers, architects, builders or contractors, are also important decision-makers. Others include public sector groups--those who establish incentives and set rates, those who establish codes and standards, those who establish public policy in commerce and welfare areas.

Nationally, a goal of providing 20% of our energy needs from renewable sources by the end of the century has been established. Such a goal can be met if and only if a number of decision-makers in the public and the private sector are provided with thorough, regionally specific, credible information on which to base their decisions.

The four Regional Solar Energy Centers which have been established by the United States Department of Energy are intended to provide a focus for the acceleration of the commercialization process for solar energy applications, and for conservation integral to solar applications. Meetings such as this one--in which detailed discussions of lessons learned in real field applications of solar energy--are good examples of what needs to be done in all twelve states served by MASEC. We are all here to learn and to share experiences of what works and what doesn't--of what to do again as it has been done, and of what to avoid. In this way we can accelerate solar utilization--we can develop a new industry.

Design and Construction of Two Passive, Solar Residences: Sondreal Residence, Amery, Wisconsin Passive Solar Retrofit, Minneapolis, Minnesota

by: Peter John Pfister

INTRODUCTION:

The Department of Housing and Urban Development awarded two grants to the author under RFGA-8600; one a design award for a residence constructed in Amery, Wisconsin; the second a design award for a retrofit of the authors residence in Minneapolis. Both projects are nearing completion as of June 15, 1979.

SONDREAL RESIDENCE:

A private single family residence was designed for a family of four in the small town of Amery in Northwestern Wisconsin. The site selected was a corner lot with access from the street on the east and with a potential street extension on the South. The site is essentially flat with no significant vegetation.

The design solution was to locate the 1,700 square foot residence on the northeast end of the 300' x 150' lot with the garage on the north side of the residence and primary living areas oriented south with access to a patio/courtyard (see Figure 1). The house is nearly cubic in configeration to minimize envelope area and construction costs. The floor plan was split along an east west line so that there is a half level change between major living areas (see Figure 2). This allowed the activity areas to be located a half level below grade. The outdoor patio area, which is also a half level below grade will be shielded from the future street on the south with additional berms and planting.

The passive solar system is a direct gain type with thermal storage in exposed masonry walls, concrete floor finished with quarry tile supplemented with water wall storage. A summary of major design features include:

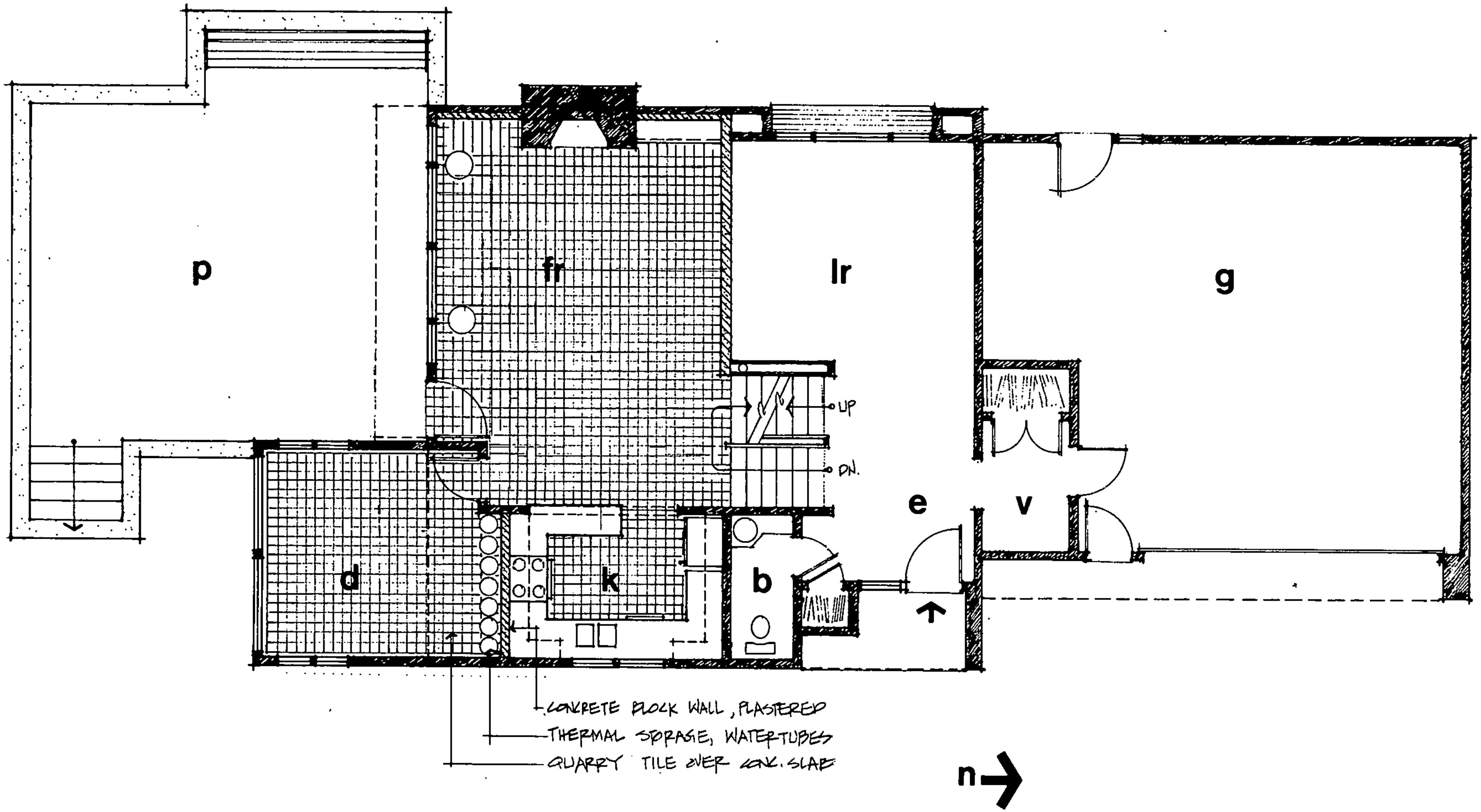
1. Net south facing aperture area of 255 square feet.

2. 7,500 BTU/^{o}F thermal storage in floor, walls, and water storage.

3. Masonry storage walls are standard concrete blocks filled with sand and finished with "Block Bond".

4. Garage entrance and formal entrance at east, opposite prevailing winds. Main family entrance through vestibule from garage.

Figure 1. Sondreal Residence



Sondreal Residence

Lower Levels Plan

Figure 1.A Lower Level Plan

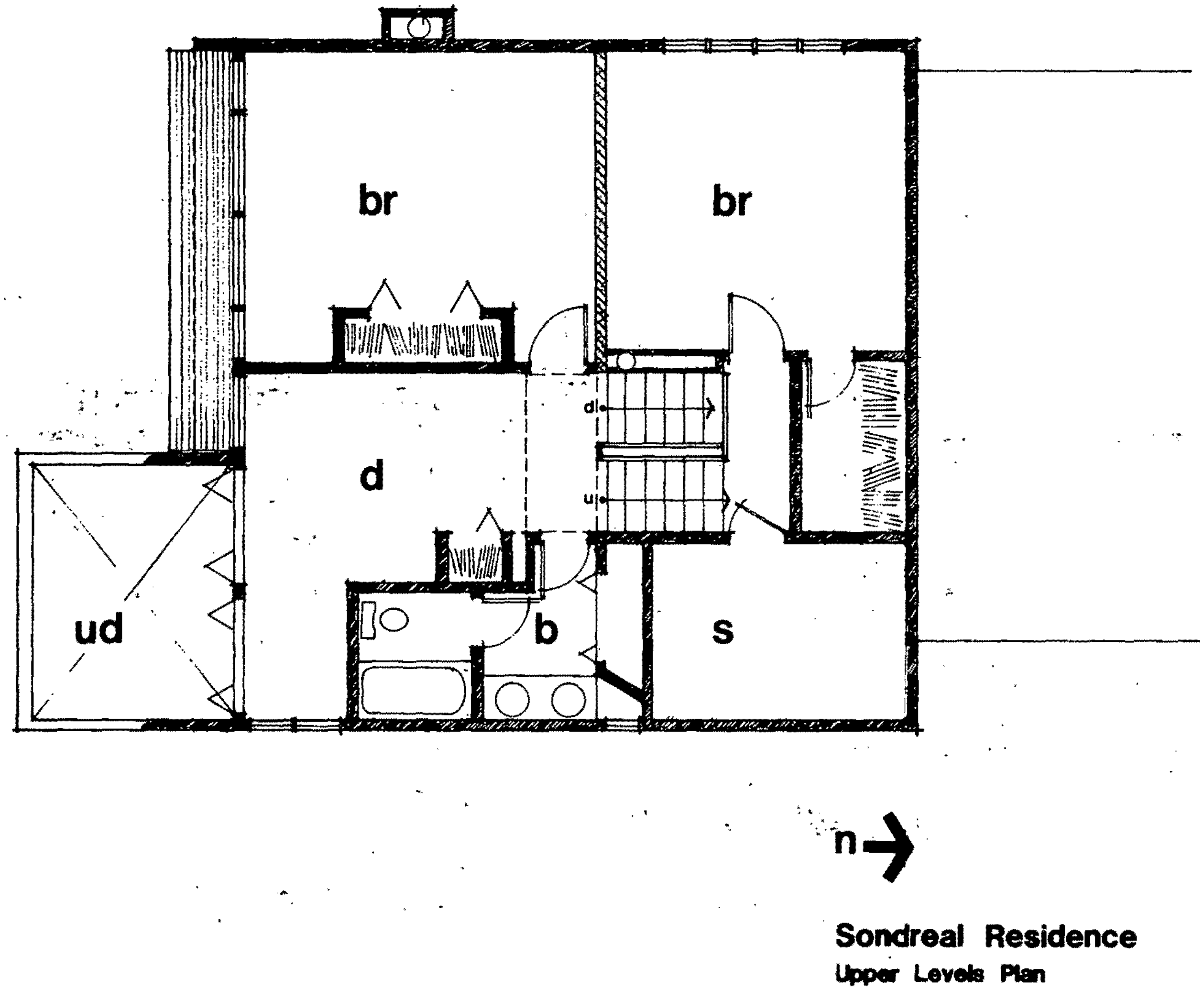


Figure 1.B Upper Level Plan

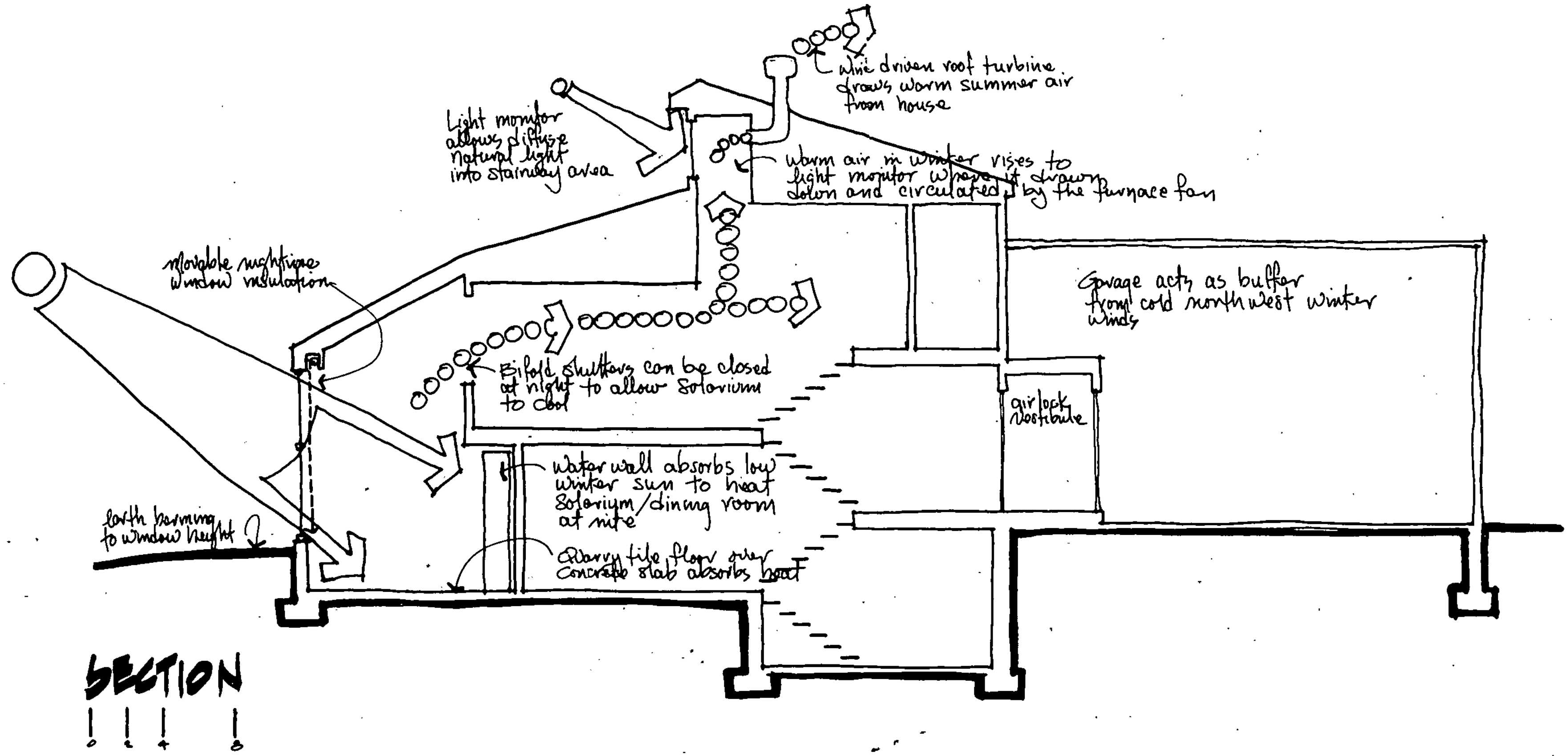


Figure 2. Section Through Dining Room/Solarium

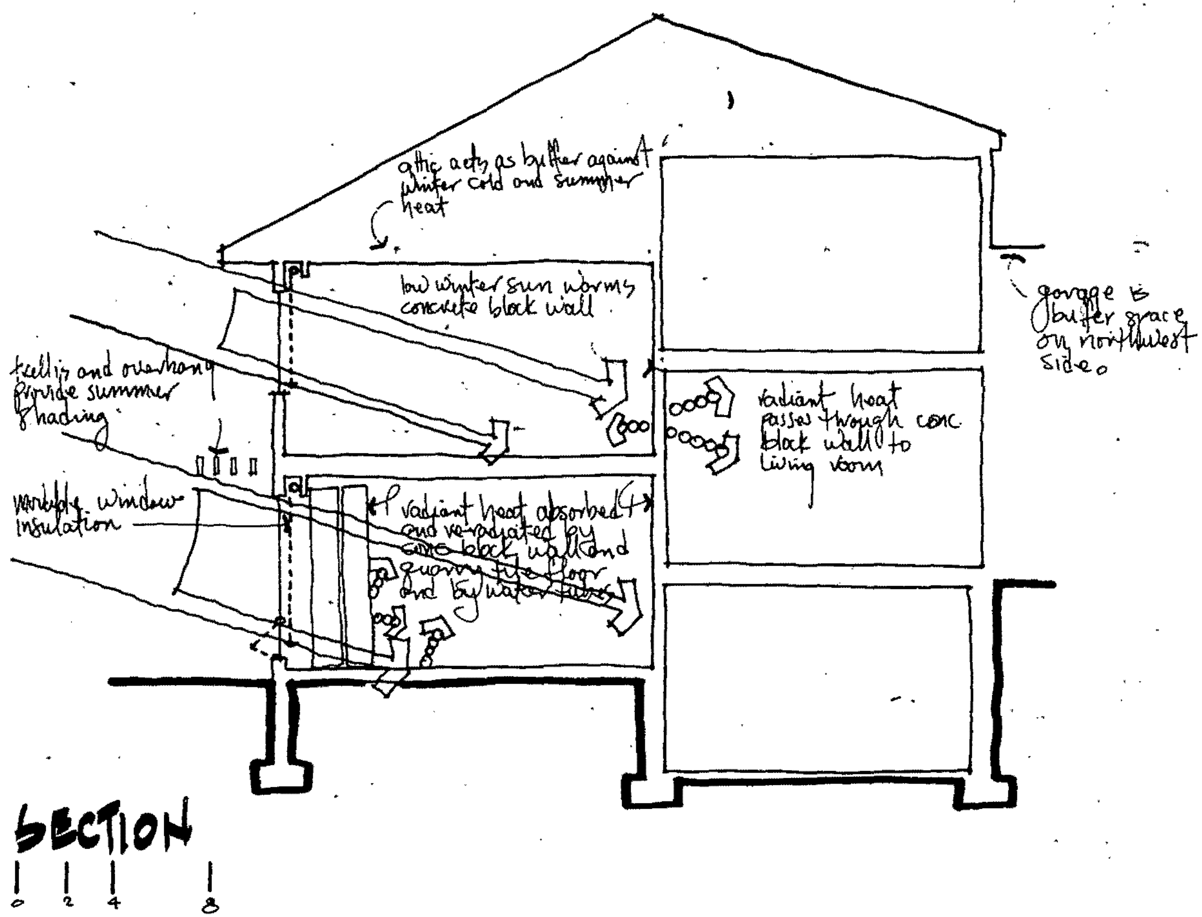


Figure 3. Section Through Family Room

5. Operable windows allow cross ventilation through house supplemented with wind turbine at light monitor.

6. All activity rooms are oriented south and east, with patio at south and garage and formal living areas at northwest.

7. Landscape plan to develop windbreak at northwest, deciduous trees at south.

8. Well insulated building shell with R21 sidewalls and R40 ceiling.

9. Triple insulated glass on north east and west (minimal), double insulated glass on south with movable night window insulation.

10. Simple air distribution system which allows warm air to rise and flow through major spaces and then circulated with the furnace fan.

The passive solar contribution is estimated to be 55 percent with a common basis figure of 3.3 BTU/DD/SF.

The residence was completed and occupied in late June, 1979.

PASSIVE SOLAR RETROFIT

An 1,800 square foot, two story frame residence located in South Minneapolis was purchased by the author in June, 1978. The residence, built in 1920, was insulated during the summer of 1978. Polystyrene beads were blown into the sidewall cavities to achieve R-16 and the attic was insulated to R-40. Additional weatherstripping, caulking, installation of water-saving showerheads and laundry reduced the annual gas costs from $750 to $300.

The major window orientations were to the north and west, with a "Sunroom" located on the northwest corner of the building. The building had very few windows on the south and poor orientation to the back yard on the south.

In May, 1979, construction of a passive solar retrofit was commenced (Figure 4 shows the renovation in progress). The major thrust of the retrofit was to increase the glass area on the south, increase thermal mass within the building and improve the relationship between the living areas and the rear yard.

The goals of the project are:

1. Improve thermal envelope of the existing building;

2. design and install a simple passive system with typical components that can be used on other retrofit projects;

Figure 4. Retrofit From South During Construction

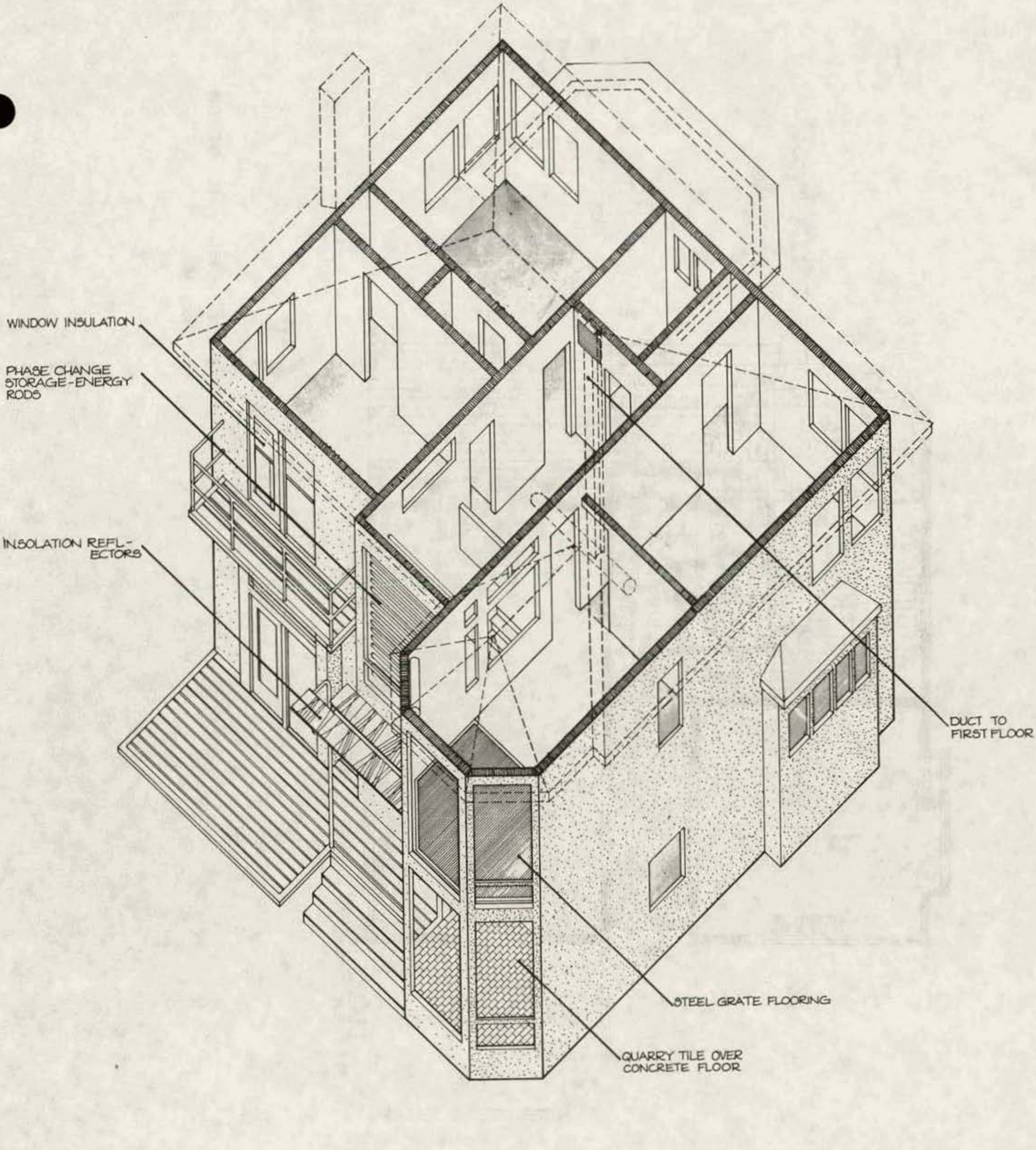


Figure 4.A Retrofit - Axonometic

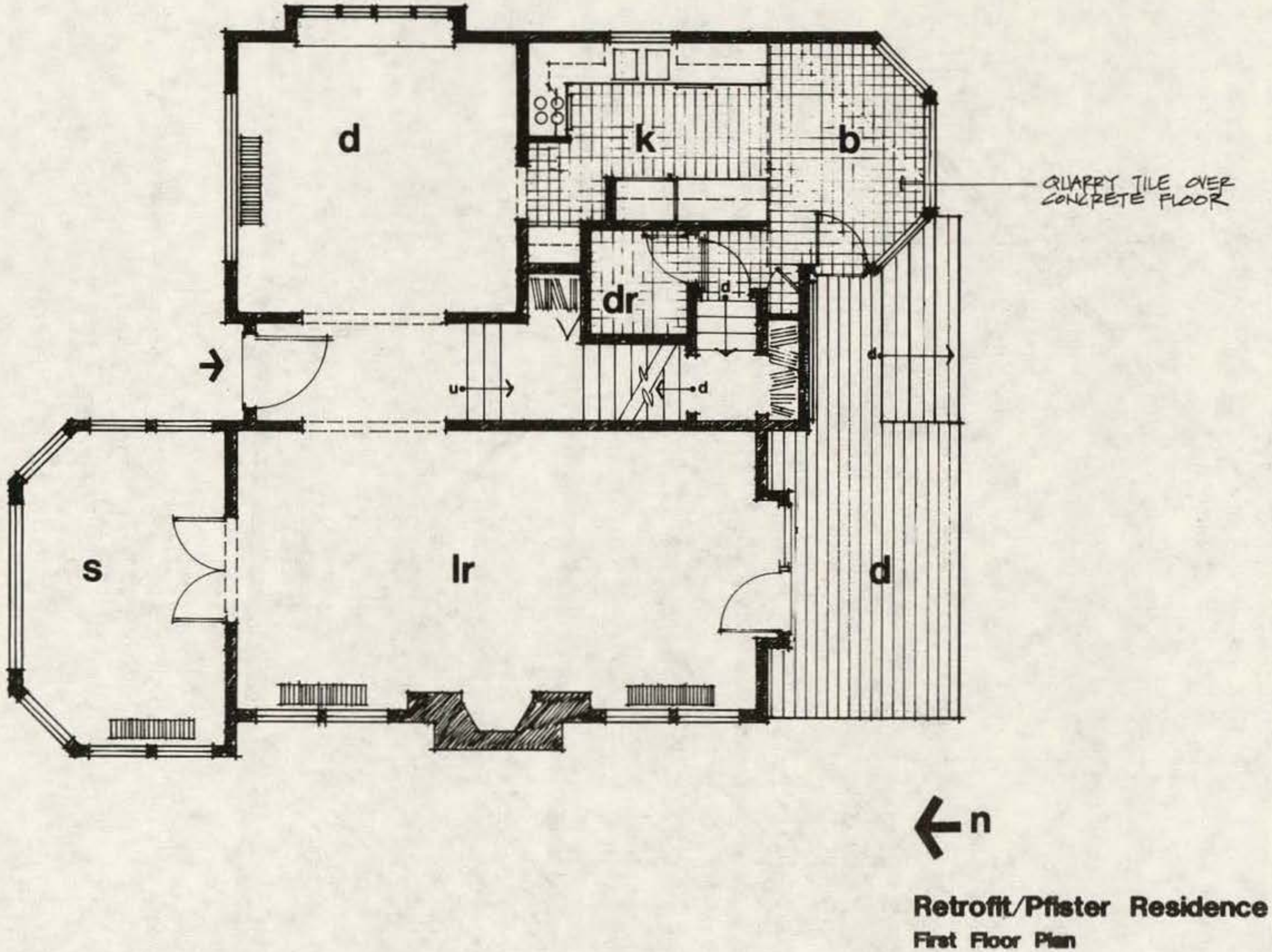
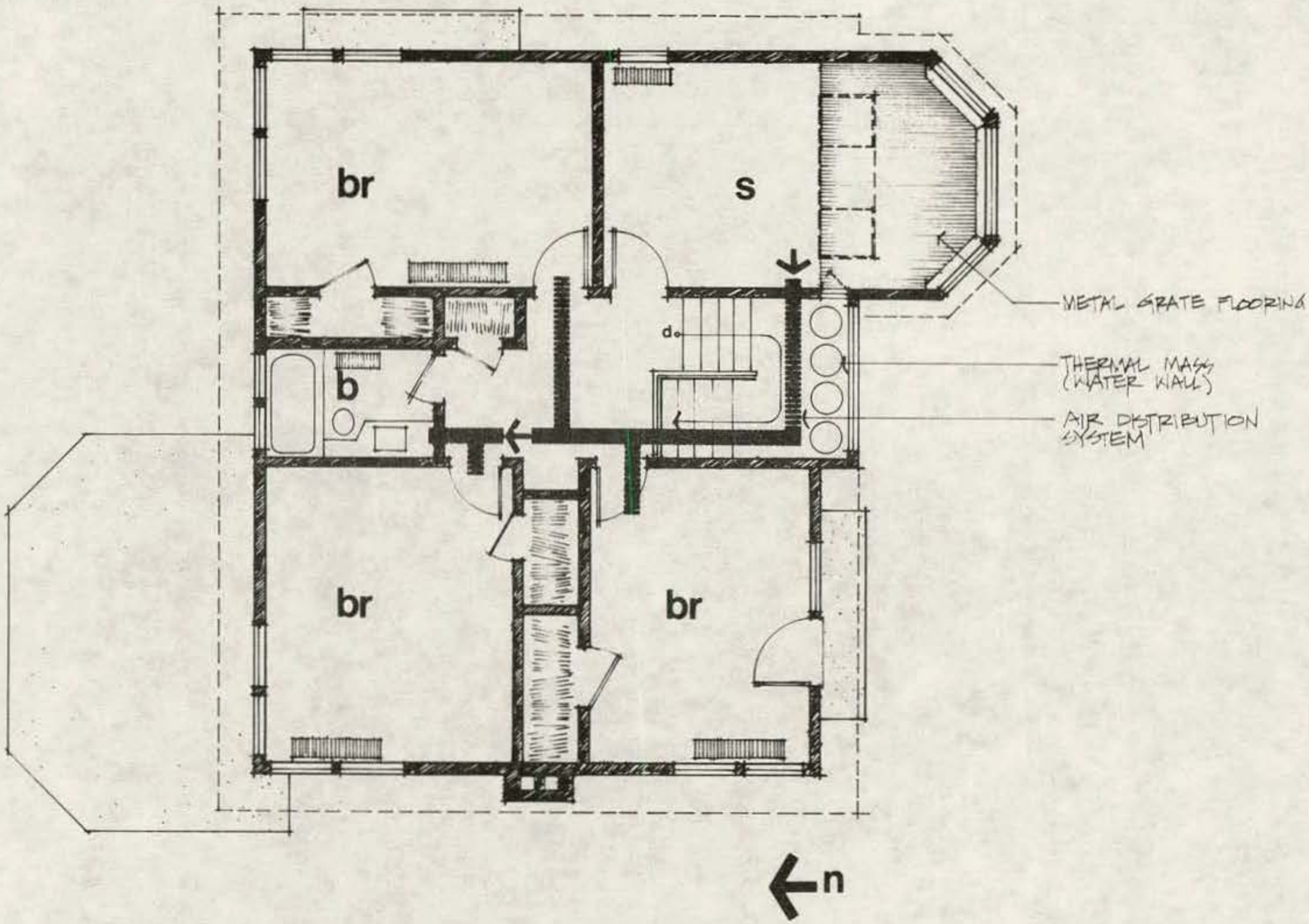


Figure 4.B Retrofit First Floor Plan



Retrofit/Pfister Residence
Second Floor Plan

Figure 4.C Retrofit Second Floor Plan

Figure 4.D Completed Retrofit

3. optimize use of passive solar gain;
4. interface with existing heating system;
5. thermally insulate windows at night time;
6. integrate thermal mass into an existing building;
7. improve the function and aesthetics of an existing residence;
8. improve the cross ventilation characteristics of the house for summer cooling;
9. assess the impact of passive system by instrumenting and monitoring the building;
10. assess the effectiveness and problems of movable window insulation;
11. publicize the results of the project to promote the use of passive solar energy.
12. development of principles applicable to other retrofits.

The key components of the project are:

1. 220 net square feet of south glazing
2. thermal storage in new and existing concrete flooring
3. waterwall thermal storage augmented with thermal siphoning air collector
4. distribution of passive solar heat augmented with fan and duct air system
5. movable window insulation to protect new and existing windows.
6. retrofit construction in a typical urban area

The existing windows of the residence are located mainly on the north and west elevations of the house. The south elevation had few existing window areas that were enlarged to accept more passive solar gain and to make the house relate better to the rear yard. The major passive collection areas added are:

1. The addition of an 8' x 12' two story high solarium to the kitchen/breakfast area. This sunspace will allow direct gain to the building and allow the warm air to rise to the ceiling where it will be circulated to other spaces on the north side of the

residence. The basement space under the kitchen and dining rooms originally was a drive under garage approached from the north. The ceiling of the former garage was constructed of 10" thick concrete to serve as a fire protection. This concrete will be insulated underneath and used as thermal storage.

2. The stairway landing leading to the second floor was projected out to accommodate water storage tubes. This waterwall area is glazed on both the inside and outside to provide an enclosed chamber. Additional glazing is located on the opaque wall below the waterwall to serve as a thermosiphoning air collector to boost the temperature in the confined waterwall space. Warm air will be withdrawn from the top of the waterwall space by a fan and distributed through the house, or the interior glazing can be opened to allow convective and radiation transfer.

3. The small windows in the window bay at the living room south wall were removed and replaced with glass doors to allow direct gain to the living room.

4. Additional glazing was installed in bedroom #3.

The existing gas fired 140,000 BTU/hr. boiler will be modified to reduce its capacity to about 60,000 to 80,000 BTU/hr. to reduce cycling. The gravity hydronic system may be fitted with a circulating pump to improve the response time and minimize overheating if this continues to be a problem after the boiler output is reduced.

Because of the existing hydronic heating system and room structure of the residence, a limited air moving system will be installed to distribute heat from the warm sunny spaces to the cooler north spaces. Exposed metal spiral ducts will be hung below the existing ceilings (9'-0" ceiling height first floor, 8'-6" height second floor). Each room will be fed with a duct above the door head and the diffuser will be equipped with a damper to control output and to shut off the room if desired.

The building heat loss has been calculated to be about 65,000 BTU/hr. (85^o temperature differential). The solar heating fraction using this heat loss is estimated to be about 45% with a common basis figure of 5.9 BTU/DD/SF. However, during monitoring over the past year, the heat loss was estimated to be about 45,000 BTU/hr. at design conditions, so that a larger solar heating fraction may be realized.

SUMMARY:

Both residences will be operated for their first heating seasons in the 1979-80 winter. The retrofited building will be extensively instrumented and monitored (under separate DOE funding) during that heating season and the results will be reported at future conferences.

A SOLAR HEATED GARDEN APARTMENT COMPLEX
LEADS TO MORE & MORE SOLAR SYSTEMS

Gustavus G. Hancock, Ph.D.

INTRODUCTION

The economic pressure of increasingly higher operating costs, particularly fuel costs, upon non-profit institutions is severe. Their mechanisms for increasing operating revenues are more limited than those of many businesses, and the life cycle of their buildings is frequently much longer. It was in this context that Great Lakes Solar Engineering, Inc., was retained by the Ray Graham Association to design and build a solar system for their new garden apartment complex, Sunrise Courts.

The building, designed by Weese Seegers Hickey Weese, Ltd., houses 22 physically handicapped persons, all in wheelchairs. This dictated a single story building, with the disadvantage of increasing the building heat load on a per square foot basis compared to a building with a smaller thermal envelope. The advantage of this design, however, is that it presents a larger potential area for solar collector erection. The completed building is shown in Figure 1.

The project has a HUD solar demonstration grant, and it is an instrumented project.

SOLAR DESIGN DATA

Building Heating System:

Building floor area - 11,400 ft^2
Solar Collector area for heating building - 4,011 ft^2, single glazed Chamberlain steel absorber plate collectors, black chrome absorber surface.

HEAT STORAGE: 20,000 gallons water, underground uninsulated steel tank, buried underneath building inside insulated footing of building.

OPERATION: 50% ethylene glycol/50% water circulated through solar collectors and shell side of shell and tube heat exchanger, transferring heat into underground water heat storage tank. Building is zone heated, with 8 York (Borg Warner) water-to-air heat pumps, drawing water from underground storage tank in closed loop. Electric coils used for heating back-up.

DOMESTIC HOT WATER SOLAR SYSTEM:

336 ft^2 single glazed Chamberlain steel absorber plate collectors, black chrome absorber surface.

PRE-HEAT TANK: 336 gallons

Taco SSM Heat exchanger system, with propylene glycol circulated through solar collectors. Secondary heating by 350 gallon electric heating tank, with recirculating system.

FIGURE 1

SOLAR DESIGN, BUILDING HEATING SYSTEM

The basic design is a solar-assisted heat pump system. Figure 2 shows the operation of this system.

The fundamental advantages of this concept are multiple. Seasonal heat load and solar climatic conditions in the Chicago region lead to an optimum solar design with approximately 65-75% of the building heat provided by the solar system, and the balance by the electric heat input. The water-to-air heat pumps operate within this range, with approximately 67% of the heat output of the heat pumps coming from the water source (solar heated), and 33% coming from the electric power consumed by the compressor and air circulating fan. Additionally, the use of heat pumps permits the operation of the solar

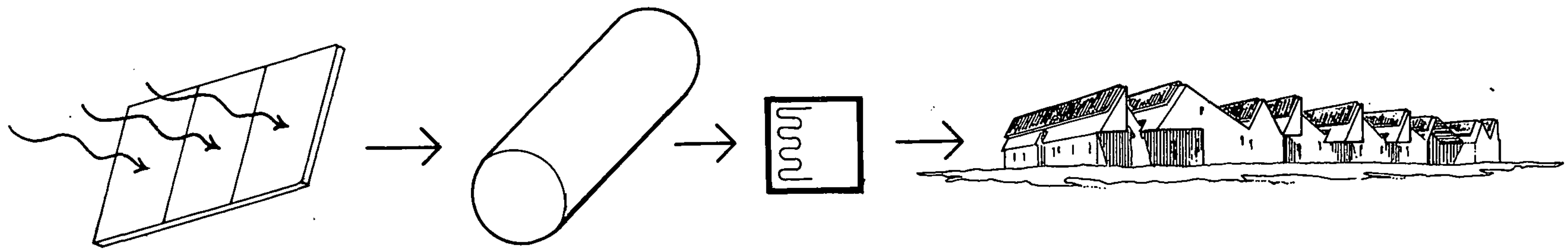

TEMP. APPROX. 65-80° F.
SOLAR COLLECTORS
4,011 S.F. (SINGLE GLAZED)
TEMP. APPROX. 45-60° F.
20,000 GAL. UNDERGROUND STEEL TANK WITH NO INSULATION (AVE. GROUND TEMP. 55° F.)
8 HEAT PUMPS
(WATER / AIR)
± 72° F. 11,400 S.F. BUILDING

FIGURE 2

collector system and heat storage tank at much reduced temperatures. The construction cost savings and increased efficiency of the solar collector are both multiple and large.

The solar heated underground water storage tank has a normal operating range of 45-60 degrees Farenheit. Operating experience has shown the heat pumps can operate with water as low as 41 degrees, and the upper limit is 90 degrees. This wide range permits storage of a high quantity of heat per unit volume of water. Since the water temperature is at or below ground temperature for the depth of the tank, no tank insulation is required. In fact, during the peak heating load season some heat is actually gained from the surrounding earth. In the months prior to the winter heating season, the solar system is operated to heat up the storage tank and surrounding earth with the earth acting as a storage battery. During this period, the solar system is used to "charge up" the earth surrounding the storage tank.

The operation of the heat storage tank and solar collectors at such a moderate temperature additionally increases the instantaneous solar efficiency of the solar collectors. Much of the piping to the solar collector arrays is run inside the building thermal envelope and with the operating temperature of the glycol loop close to the normal room temperature, the need for insulation of the piping is eliminated - a substantial cost reduction.

SOLAR DESIGN, DOMESTIC HOT WATER SYSTEM

The domestic hot water solar system is completely independent of the building heating system. It was designed to solar heat a pre-heat tank, which then feeds into a standard electrically heated tank. A modular Taco Solar Systemizer was used, with the solar collector fluid circuit and the pre-heat tank water simply "plugged into" the module. The initial design called for two 350 gallon pre-heat tanks, with 336 ft^2 solar collector area. Budget reductions and space limitations forced the elimination of one 350 gallon pre-heat tank.

CONSTRUCTION

Relatively few construction problems were encountered. All copper piping was used in the antifreeze and heat pump water circulating systems. A critical design problem was the connection of the solar collectors to the header pipes to permit adequate thermal expansion and contraction. Silicone hoses with clamps are expensive, and were judged prone to leaking over the long term. Flexible hydraulic hoses are also expensive, when considering that 414 are required for the 207 solar collectors. The problem was solved by using a specially fabricated "S" shaped soft copper tube between the collector and header, so that the connection to the header is offset from the connection point into the collector. The radii of the bends in the soft copper tube have adequate flex to absorb any movement of the headers relative to the fixed positions of the mounted collectors. All connections are seated in the normal manner, and the piping trades people were much more comfortable with this type of connection than with making hose clamp connections, particularly when the joint must be covered with insulation and sheet metal ridge caps for many years without the possibility for easy access.

Many alternatives were considered for the mounting of the collectors on the saw tooth pattern roofs, including steel and aluminum channels laid on the roof. The technique finally used was to lay Wolmanized wood 4 x 4's horizontally under the tops and bottoms of the collectors. They were fastened to the roof with galvanized post bases, keeping the 4 x 4's 1/2 inch off the roof for adequate water drainage and air breathing. Most important, the use of wood 4 x 4's permitted the use of a long-reach light crane to sling the collectors up onto the 4 x 4's to hang by their corner brackets. One crew of carpenters worked slinging the collectors up onto the roof, while another crew followed behind, lag bolting the collector brackets onto the 4 x 4's. The positioning tolerance afforded by the wood for the brackets was a distinct advantage over metal supports.

Sheet metal pitch pots were used for the solar collector pipe penetrations through the roof. They were made up special to accommodate the unusual roof pitch which matches the solar collector tilt angle of 52°.

MAINTENANCE

The solar system has not operated through a full season, so relatively little can be said regarding maintenance. The initial start-up of the system was somewhat complicated by the use of steel absorber solar collectors which require careful flushing over a 48 hour period with a special caustic solution. After the caustic was run in the system for 48 hours, it took several days to flush the system with water, which was followed closely by filling the system with anti-freeze for corrosion protection. The start-up procedure is much simpler with an all copper system.

During the summer months when the building heating system is not used, the steel absorber plate solar collectors require draining of the glycol system and flushing with dry nitrogen to eliminate all moisture and prevent corrosion of the steel. This is an additional maintenance burden caused by steel absorber plates.

CONCLUSIONS

Overall, the problems with the installation have been minimal. The use of the low temperature solar system combined with water-to-air heat pumps in this project has led to a considerable number of other projects for our firm using the same principle, but substituting both outdoor and indoor swimming pools for water/heat storage. The normal temperature of a swimming pool (80 to 82 degrees) is within the heat pump operating range. Most installations are using single glazed copper collectors, but we have one installation under construction in the Florida panhandle using our standard unglazed plastic swimming pool collector. This works fine and is very cost effective where the swimming pool water can be circulated directly through the solar collector, when freezing is not a problem.

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EVERYTHING YOU WANTED TO KNOW ABOUT SOLAR IN SEATTLE BUT WERE TOO PESSIMISTIC TO ASK!

BY

TERRY L. BRATVOLD

The State of Washington has the widest range of weather conditions in the United States. From the desert regions of Eastern Washington where temperatures often exceed 100° and annual rainfall is below 10", to a small region in the Olympic Peninsula in Western Washington where the mean annual precipitation is 240". This is the heaviest in the continental United States. A sunbelt exists just forty miles to the northeast of this damp region around the town of Sequim, which has an annual rainfall of 15" to 20". Seattle is situated forty miles to the southeast of this sunny area in the mild climate of the Puget Sound. Seattle's mean annual rainfall is only 30" to 35". [1]

The percent of possible sunshine for Seattle is approximately 50% annually under which a solar system with the appropriate tilt receives as much solar insolation as any geographic location. The performance of a solar system under cloudy conditions fluctuates greatly with the type of solar equipment and the infinitely varying cloud conditions. The Solar Department of Washington Natural Gas Company has been monitoring some of our installed solar systems in the Seattle area and has found that flat-plate solar collector systems perform impressively under many cloud conditions. We have recorded flow temperatures as high as 163° on a completely overcast day of medium to light cloud density. Quantitative analysis of this performance is nearly a science in itself and needs to be developed further as the first question asked is "How well does solar work in Seattle or in Dearborn?"

The second question may be "Why is a natural gas company involved in solar?" Washington Natural Gas Company has been diversifying in energy and the conservation of energy for several years through the

1. Isohyetal analysis prepared by the U.S. Weather Bureau Forecast Center, using adjusted climatological data - 27 year average.

marketing of more efficient heating, conservation and solar equipment. A parent company was formed in 1978 named the Washington Energy Company which has four energy subsidiaries: Washington Natural Gas Company (WNG), Thermal Efficiency Inc., Thermal Energy Inc. and Thermal Exploration Inc. The three TEI's were previously subsidiaries of WNG. The business affairs of these companies reach many states with the common goal of energy supply and the efficient use of it.

Washington Natural Gas Company is primarily engaged in distributing natural gas, but also merchandises energy related products including solar equipment within our service area. Thermal Efficiency Inc. (TEI), is a distributor of solar equipment in a four state area. WNG and TEI working together have installed over sixty-three solar systems in the last three years, fifty of which are in Western Washington. These systems range from two panel domestic water heating systems, swimming pool systems, space heating for homes and commercial buildings, to a sixty panel system on Overlake school. The manufacturers of most of these systems are Solaron of Denver, Colorado, and Fafco of Menlo Park, California.

Several years ago, as we began researching the solar market, we found that the technology, patents and manufacturing of flat-plate solar collector systems had been around since at least 1899. In fact, we found the technology in flat-plate collectors to be near its peak. Our concern was to find manufacturers with quality in equipment and supply, design assistance, training, and warranty services. Solaron and Fafco have provided us with these services over the last three years.

This is not to suggest that there are not other reliable solar equipment manufacturers, there are. However, many of the manufacturers, large and small, are finding it difficult to survive the slowdown of 1978. Even though retail sales of solar equipment have increased fairly steadily, the orders to the manufacturers, in many cases, have not. The reason for this was that many distributors and retailers over-stocked during 1976 and 1977 in anticipation of a solar sales surge with the passing of the Federal Solar Tax Credit and other expected Federal support. When the surge didn't happen, distributors and retailers held back on new orders to the manufacturers until their solar inventory was reduced. This situation is somewhat self-correcting as retail sales increase. It does, however, make us more aware of the need for choosing a supplier that can supply service now and ten years from now.

WNG's first awareness of the need for careful selection in solar equipment manufacturers came with Solar Home I three years ago. It was a four panel solar assist, water to air, space heating system. The freeze protection system failed and froze and the tedlar glazing shrank and split.

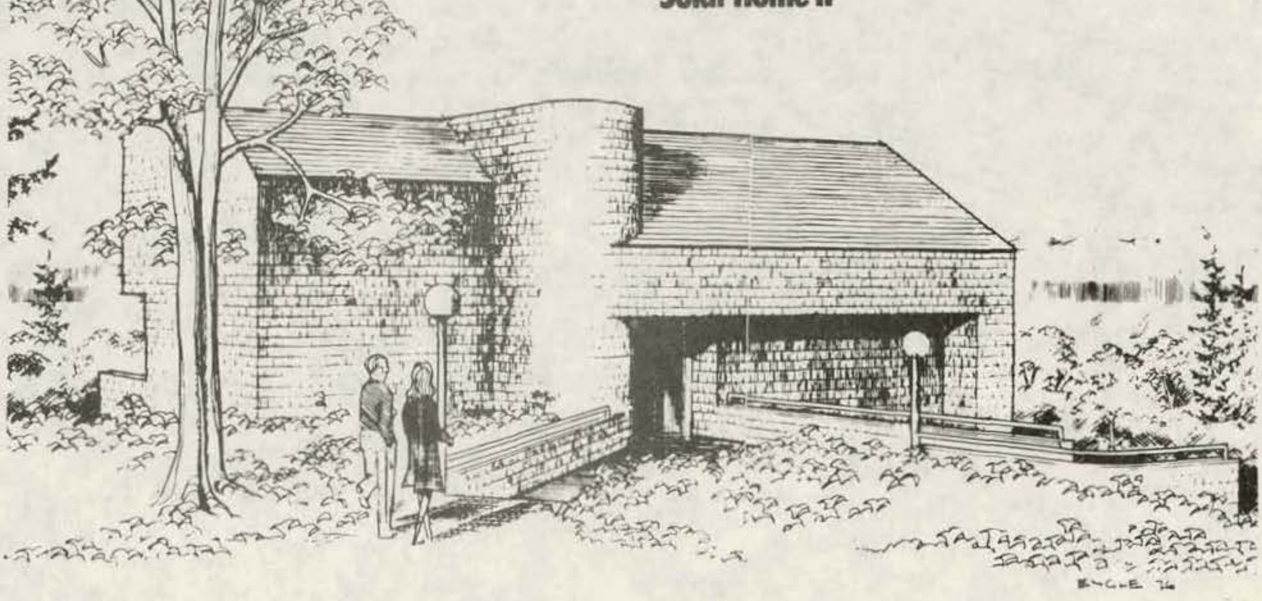
Undaunted and a bit more experienced, we proceeded with Solar Home II in 1977. This time we hired an architectural firm with a considerable amount of experience in solar design, Omar Mithum and Associates.

At that time, Thermal Efficiency had become a distributor of Solaron Systems. The technical services people at WNG and TEI worked closely with the architect and the Solaron engineers who provided design and computer services. We applied for and received a HUD Cycle II grant under the National Solar Heating and Cooling Demonstration Program, to assist in the cost of the solar system. HUD also elected to monitor Solar Home II for up to five years. This was especially fortunate for us because Boeing, who is the monitoring instrumentation contractor for HUD nationwide, is a neighboring company in the Puget Sound area.

The purpose of Solar Home II was to demonstrate to the public and the professional community what we believed: solar systems active and passive, if properly designed and installed, will perform efficiently in Western Washington. We also realized that for a technological concept such as solar to be accepted in the Northwest, a trend must be set. Solar Home II and the other sixty-two solar installations we've been involved in over the last three years are helping this trend. One measure of public interest is the approximately four hundred requests received monthly, for information and solar equipment bids at WNG's Solar Department and Marketing Department.

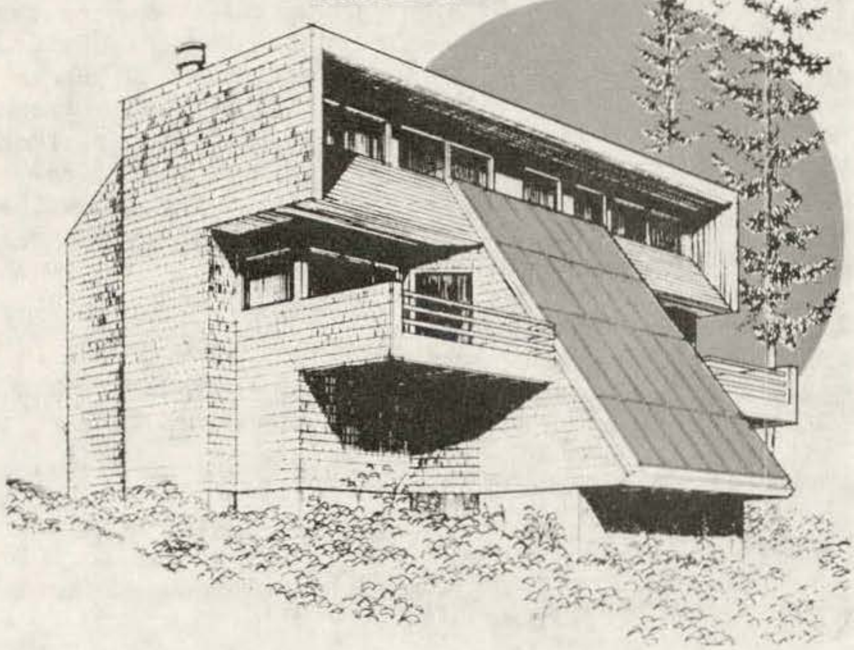
Perched on a hillside near beautiful Lake Washington, Solar Home II is a blending of contemporary design and modern energy science. WNG spec-built the 2860 square foot house and construction was completed in November 1977. Open house was held during the next ten months for over four thousand visitors from the public, professional and educational sectors in Washington State.

Solar Home II



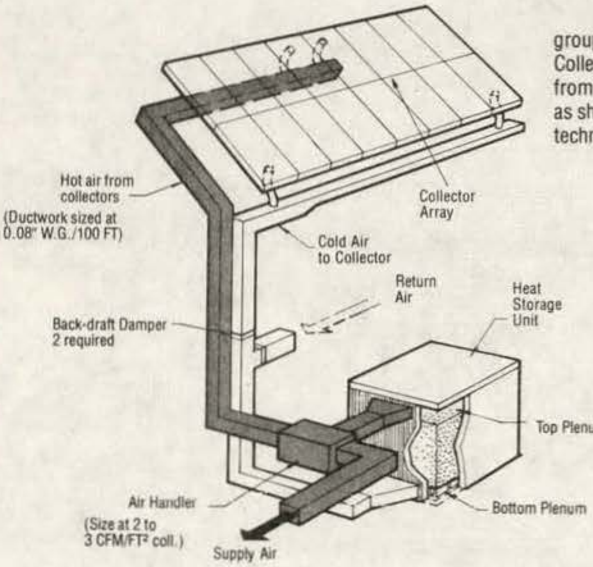
Solar Home II was sold to the Farnham family in October '78. Since then, Paul, Louann and their newborn have been living there comfortably and are very pleased with their solar home. Paul enjoys the innovation of owning a home heated by an active and passive solar system. Louann enjoys having only to adjust the thermostat and the blinds to be comfortable year round.

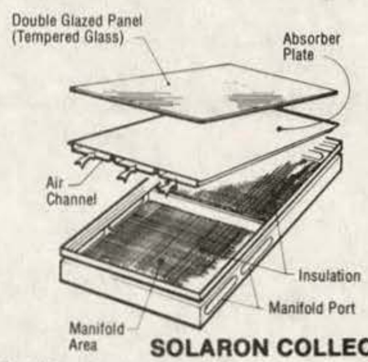
Solar Home II



GENERAL SYSTEM DESCRIPTION

A drawing of a typical installation is shown to the left. The collectors can be grouped as shown or in any of the configurations shown on page 2, Typical Collector Arrays. Due to the Solaron internal manifolding technique (i.e. air flow from one panel to another internally) the external duct connections are minimized as shown above (i.e. one inlet and one outlet for 8 panels, 156 ft.^{2}). This technique reduces field labor and leads to an economical installation.



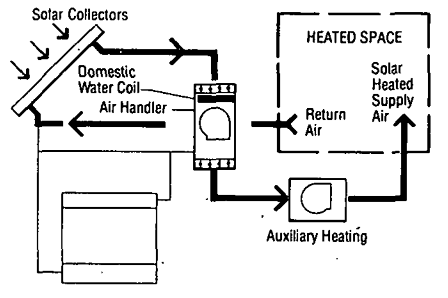


SOLARON COLLECTOR PANEL

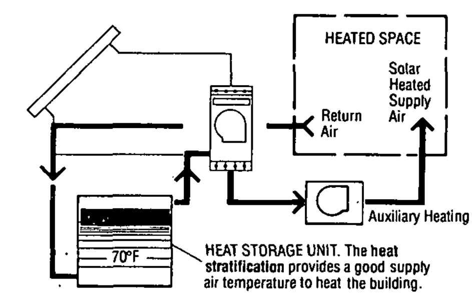
Note: Air flows thru the channels **beneath** the absorber plate.

The selling price of Solar Home II was in the same price range as other non-solar homes in the area with similar floor space. The retail value of the solar system was $16,380 at the time of completion in 1977. However, the home was designed around the solar system in such a manner that the cost was incorporated into its structural and aesthetic features. The collector surface is the roof over the kitchen on the main floor and over the mechanical room in the basement. The rock storage was sunken and out of the way. These and other design considerations are important in determining the true cost of solar systems in new homes. As these design concepts and solar technology become more widely accepted the consideration towards the solar system as a capital investment with profitable returns becomes appropriate.

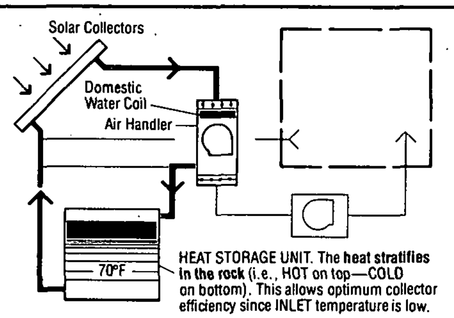
SYSTEM OPERATION



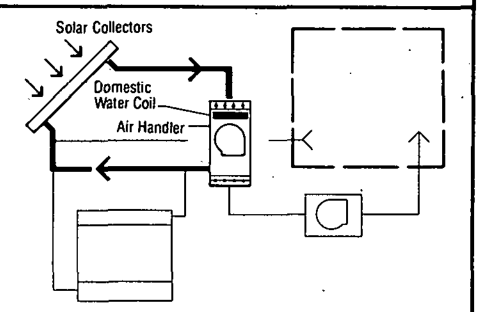
HEATING FROM COLLECTOR Air, the circulating heat transfer medium is drawn through the collector where it is normally heated to about 120-150°F. When the space requires heat, the solar heated air is drawn through the air handling unit in which motorized dampers are automatically opened to direct the hot air to the space. The air then returns to the collector where it is again heated and the cycle repeats itself.



HEATING FROM STORAGE At night or on cloudy days when solar energy is unavailable and when heat is needed in the space, the automatic control system directs the building return air into the bottom of the heat storage unit, up through the pebbles where the air is heated, through the air handling unit and into the space. When the solar heated air does not maintain the space thermostat setting, the automatic control turns on the auxiliary heater to add to the required heat.



STORING HEAT When the space temperature is satisfied the automatic control system diverts the air into the heat storage unit where the heat is absorbed by the pebble bed. The air returns to the collector where it is heated and this cycle is repeated.



SUMMER WATER HEATING In the summer, when space heating is not required, air is drawn through the collector where it is heated and then through the water heat exchanger coil. The solar heated air transfers its heat to the water which is being circulated through the coil and the air is then returned back to the collector inlet.

System Description

Solar Home II uses solar energy to heat the 2860 square feet of living space and to heat the domestic hot water (DHW). The solar energy system has an array of 28 flat-plate collectors with a gross area of 591 square feet, collector area of 546 square feet (3ft. x 6.5ft. panel dimension), and a net aperture area of 504 square feet. The array faces south at an angle of 57° to the horizontal. Air is the transfer medium that delivers solar energy from the collectors to storage and to the space heating and hot water loads. Solar energy is stored in a 273-cubic foot bin (6½ ft. cube), containing 27,300 pounds of smooth stones, averaging 1" in diameter. The bin was constructed of concrete in the basement floor and has 2" of styrofoam insulation on the outside and 1" of high density fiberglass insulation on the inside. The domestic hot water is heated in an air to water fin-coil heat exchanger, located in the hot air duct returning from the collector array outlet. The hot water is circulated to an 80 gallon natural gas automatic water heater used as a back-up. When the demand for space heating is greater than the solar system can satisfy, a natural gas furnace provides auxiliary energy.

Solar Home II has only 70 square feet of windows on the non-south sides to reduce heat loss. The south side, however, has 500 square feet of double glazed windows for passive solar gain in addition to the 546 square feet of double glazed solar collectors. The home's construction optimizes the use of sidewall and ceiling insulation to the R factors of 19 and 30, respectively. Other energy-conserving products in Solar Home II include spark ignition natural gas appliances and a sealed-combustion fireplace. The results of these energy saving features is that the heat loss from Solar Home II is about 60% less per year than a standard home its size.

The F-Chart computer thermal analysis for Solar Home II and the Farnham family compute the solar fraction for the active solar system to be 48% annually. In addition, the passive solar is estimated to contribute better than 25% to the space heating load. Totally, the active-passive hybrid should provide an approximate 75% solar contribution.

Solar Home II has been occupied by the Farnhams only since the third week in October 1978. Thermal protective chrome-faced Levelor blinds for the windows were installed in March 1979. We were fine tuning and adjusting airflow on the solar system up until January '79. Also, the Boeing engineers were calibrating some of the monitoring instrumentation into January. Because the home has not been lived in for a full year at this writing and the other above mentioned occurances, a complete "bottom line" performance analysis is still forthcoming.

However, a great deal of performance data and actual experience has been gained to date. In fact, the value of the before and after fine tuning comparison study and hands on experience is of equal value to a data-logged computer performance report. Fortunately, we have both.

Preliminary performance calculations with adjustments for the above mentioned occurances, show a solar fraction of heat load at 67% for the six month heating season of 1978-79, October through March. At the end of the second six months, calculations for a year will be possible. For the time being, we are able to calculate the second six months expected performance using the available months actual values with F-Chart weather and performance values. The conclusion is an active plus passive solar fraction of heat load of 73% for the first year. The inclusion of the domestic water heating sub-system, which operates year round, will adjust that solar fraction to approximately 80%.

The performance of the solar system at Solar Home II is also being monitored by instrumentation provided by HUD under the administration of the U.S. Department of Energy (DOE) for the National Solar Data Program. Sensors were installed at 30 locations at the home to provide sufficient measurements to support the thermal performance analysis of the solar energy system. Instruments were selected and installed by DOE Instrumentation Installation Guidelines (publication #Solar/0001-77/15) and requirements of National Bureau of Standards (NBSIR 76-1137). This instrumentation includes sensor devices to monitor the following:

Total Insolation (on the collector array)
Outdoor ambient temperature
Building temperature
Collector loop flow rate and temperatures
Storage flow rate and temperatures
Load subsystem flow rates and temperature
Auxiliary fuel flows and values

Measurements are recorded automatically at five minute intervals by the Site Data Aquisition Subsystem (S.D.A.S.). This recorded data is transferred daily by telephone lines to the Central Data Processing System (C.D.P.S.) at the IBM facility in Huntsville, Alabama. The end result is a fourteen page monthly performance report. Three sub-contractors are involved in this process:

IBM Corporation (data processing and performance analysis)
Boeing Company (instrumentation)
Dubin Bloome Associates (solar design consultants)

To date we have received finished reports for the months of August, September, October 1978 and March 1979. Of these, the only full month that the home was occupied was March. The Farnhams moved in late October. Consequently, conclusions on seasonal performance from DOE are not yet available. Also, when reports do arrive, substantial time has elapsed from the actual month.

However, we do have available, by special request to I.B.M., raw data on Solar Home II for certain individual days. This data for a single 24 hour period is computer typed on 25 pages which display 8,640 numerical measurements from the 30 sensors that record every five minutes. Even though very time consuming, these figures allow us to study the intricate operations of the solar system, the home and the environment. For example, let's look at a few measurements from January 7, 1979:

12:02:20 am <u>Storage</u> temperature - 113.653° f- indicates that January 6th was a reasonably clear day and the storage temperature peak may have been as high as 130°.

<u>Outside ambient</u> temperature - 35°

<u>Inside ambient</u> temperature - 70°-Mrs. Farnham is keeping thermostat setting at 70° with no night set-back. (note: window blinds for thermal protection had not yet been installed).

<u>Furnace discharge</u> temperature - 70°- no call for space heat (note: with call for heat, furnace blower works in tandem with solar system airhandler to draw heat from storage, or collectors, or furnace burners).

12:15 am <u>Furnace discharge</u> - 110°- indicates call for heat and heat flow from storage to space mode.

12:20 am <u>Furnace discharge</u> - 135°- indicates ignition of burners to assist heating space - also indicates problem with thermostat not having enough temperature band between 1st stage solar and second stage auxiliary (1½°), when there is about 90° in storage. (We also found that when manual night set-back is practiced and morning turn-up occurs, the 1st stage is overridden to 2nd stage, thereby not fully utilizing storage heat at that time. This may be an industry-wide problem. One possible solution is the development of a 3 stage thermostat. Another could be to install a temperature switch in storage that deactivates the furnace burner valve when storage termperature is above 95°).

4:00 am Storage - 101° and decreasing - indicates heat flow from storage.

8:30 am Storage - 87° and stabilizing, Pyranometer - 105 BTUs/sq.ft./hr.- indicates discontinued heat flow from storage mode as passive solar gain is adequate to heat space.

9:30 am Inside ambient - 71° and increasing - indicates passive gain increasing.

Storage - 84° and increasing - indicates solar collector to storage mode activated.

11:30 am to 12:30 pm Pyranometer 175 to 300 BTUs (225 average) - indicates some scattered clouds with reflectance to give the 300 BTU reading.

2:10 pm Pyranometer - 175 BTUs, 50 BTUs 5 minutes later - indicates cloud cover.

Storage - 106° and stabilizing - indicates cloud cover dense enough to deactivate collector to storage mode.

Inside ambient - 77° and stabilizing - indicates overheating by passive gain (Mrs. Farnham reported heating beyond 70° by passive gain everyday of the winter, rain or shine, including the 10 day December clear, sub-freezing period during which highs of 88° were consistant. Cross ventilation was not practical because of the lack of window and door screens. The overheating was eliminated with the installation of chrome-faced venetian blinds in March. They were provided by Levelor Blinds Manufacturing Co. as a demonstration. The chrome facing proved effective in reflecting excess ultra-violet radiation. (Window screens were later installed for fresh air when desired.)

8:00 pm Inside ambient - reduced to 70° - demonstrates the ability of the house mass to store and return heat to space.

Storage - 104° - indicates no heat flow to or from storage since 2:10 pm and shows good heat retention.

9:30 pm Storage - 101° - indicates heat flow from storage to space mode and completes the day's solar system cycle.

It is important at this time to recognize the value of 15 sensors in addition to the 30 HUD sensors. These are the five senses of each of the three members of the Farnham family. Without their shared experiences with Solar Home II the other monitoring would not be nearly as comprehensible. The same is true of the owners of the other solar systems. The amount of information gained from related first-hand experience and our own hands-on involvement could not be reproduced by any amount of electro-mechanical monitoring.

The on-going monitoring of other solar systems such as WNG's own Totem Lake operating base, have provided us with immediate quantitative performance information in relation to sky conditions. Here is where we have recorded 163° flow temperatures exceeded 200°. Even on drizzly days, though not as impressive, solar system operation and storage temperature gains, have been recorded. This also allows flow rate changes to be made with immediate results observed.

The spin-off from this involvement will be far reaching. Not only will we be able to provide the expertise necessary for the fast growing solar market, but more thorough knowledge will be gained about non-solar heating systems. Now ideologies for overall energy studies will be developed. For example, we may learn that a solar system is a favorable reduction to peak load demand on clear, sub-freezing days, rather than the unfavorable low load factor previously suggested by some utilities. Also, the many methods for figuring the "pay back period" become less valid when the solar system is purchased as a capital investment with attractive returns upon resale as well as monies saved on energy reduction during ownership. The possibilities are numerous and exciting. The people of Washington State and the Pacific Northwest are starting to become involved in the solar movement.

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Washington Natural Gas
A Washington Energy Company

SOLARON
SOLAR ENERGY SYSTEMS

The time is now to approach a problem that may be very serious to the solar movement locally as well as nationally. That is the need for closer communication and cooperation between the U.S. Department of Energy (including subcontractors) and the solar equipment manufacturer.

Washington Natural Gas Company's Solar Department, up till now, hasn't faced this problem. Over the last three years we've worked closely with our suppliers of solar equipment, mainly Solaron and Fafco. They have been amiable and helpful and we've been impressed with their high level expertise. They also provided us with the technical training so necessary for the successful installation and maintenance of solar systems.

Also, since October 1976, when our HUD Cycle II grant application was selected we have enjoyed working with many people within DOE, IBM and Boeing. HUD field representative, Colin Chalmers, was always willing to help coordinate our project. IBM analyst, Clyde Messerly, has spent considerable time on the phone answering our questions on the SDAS and sending of raw data for our study. The Boeing engineers from the Special Projects Division have been especially supportive in our efforts to fine tune the solar system. Engineers, Randy Kirk, Bill Poggel and Max Gertsch have spent considerable time with us at Solar Home II surveying its intricacies.

This close association with these highly qualified engineers, the monitoring process and the training provided by the Solaron engineers have given us greater insights into what makes a solar system work efficiently or not efficiently.

Now here lies the problem, there are vast resources of knowledge and experience on both sides of us willing to share with us when we ask. But the sharing of this information is very inadequate between the Department of Energy and the manufacturers. Consequently, there are differences in conclusions as to the actual operating efficiencies of many solar systems. There are differences in the methods to calculate these conclusions.

Solar Home II is in the middle of some of these differences. Some of these differences are as follows: calculations of heat load; effects of air leaks on solar system and building performance; the effect of passive gain; the effect of auxiliary heating on performance.

The far reaching effects of these differences are confusion, frustration and a slowing of the solar movement. The solution is simple, meet at some of the sights with all parties concerned to exchange methods and solve differences. The implementation of this solution may not be easy but Washington Natural Gas Company is willing to start. We have received commitments of willingness to meet at Solar Home II from the following: Solaron Corporation; Boeing; IBM and the Farnham family.

If DOE is willing to assist, we will proceed to arrange the meeting as soon as possible. The results will be advantageous to all including the consumers, the future owners of solar systems. If we are to meet our goals by the year 2,000 it will take this kind of cooperation.

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Scattergood School's Solar Heated Recreation Building

Conrad Heins, Ph.D.

Introduction

The Scattergood School solar heating system is a Cycle I project of the Department of Energy's Solar Heating and Cooling Demonstration Program. The project was started during the summer of 1976 and completed and started up during the spring of 1977. Thus it has now been in operation for two years. This paper is concerned with the design, construction and maintainance of the system. It also discusses some of the lessons we have learned and changes we might make if we could do it all over again.

Solar Heating System Description

The heating system is a hot air system that heats the school's new 6900 sq. ft. gymnasium amd preheats water for use in the adjoining locker rooms. A collector array of 128 Solaron, Inc., 2001 flat-plate collector panels is attached at an angle of 50^{o} to the south wall of the gymnasium. The collector area is 2496 sq. ft. An insulated, reinforced-concrete box 8 ft. by 25 ft. by 10 ft., located under the collector and containing about 65 tons of washed river gravel, provides heat storage. Above the rock storage box is a 5000 cfm air handling unit. Air is distributed to the gymnasium through overhead ductwork and a series of double deflection registers. Back-up and supplementary heat is furnished by two 250,000 Btu/hr propane heaters mounted in opposite corners of the building.

The collector heats water for the locker rooms by means of a heat exchanger built into the ductwork. Water is circulated through the heat exchanger and stored in two 120-gallon, glass-lined insulated tanks; the water serves as pre-heated water for a 52-gallon, fast-recovery electrical water heater. The system was designed to provide about 75% of the space heating and about 75% of the hot water needs of the gymnasium during the heating season.

The heating system was designed for 4 modes of operation.

Space Heating from the Collector. When there is a 45^{o} temperature differential between the collector inlet temperature and the collector outlet temperature, a relay activates the air handling unit. If the building temperature is below a pre-set value, air flows into and is returned from the gymnasium. If the building load is not satisfied by the collector, the back-up heating system will turn on. Water is heated during this mode.

Storing Heat from the Collector. Heat is stored in the rock box during those times it is not being used to heat the building. Air flows from the collector down through the rock bed and back to the collector. Water is heated during this mode.

Space Heating from Storage. Air flow through the rock bed, into the building and back to the bottom of the rock box.

Water Heating Only. This mode is used during the summer. Air flows from the collector past the heat exchanger and back to the collector, bypassing the rock storage box and the gymnasium.

Design Philosophy

Simplicity was a key factor in the design of the solar heating system. Because the primary purpose of the system is to heat the air inside the gymnasium, we felt it logical to heat this air directly--hence a hot air system was selected. The use of racks as a heat storage medium, although not as space-efficient as water or eutectic salts, is the simplest way to store heat. Because we had plenty of room for heat storage, we chose rock.

A second design objective was to minimize the number of serious problems that might arise during the lifetime of the system. Here again we felt that air has a distinct advantage over a liquid heat transfer medium. There are no potential problems associated with collector freeze-up or a catastrophic loss of fluid. Another precaution, taken to avoid a possible problem with wind, was the incorporation of expensive, custom-fabricated steel columns to support the collector array. The overall structure has been designed to withstand a continuous wind load of 60 mph. Such a precaution is not unrealistic for our part of the country.

A third criterion used in design was the desirability for the system to be easily modified in order to permit expanded use. For example, the two 120-gallon hot water storage tanks are connected in series. Only minor plumbing changes are required to insert additional tanks in order to increase the water storage capacity. A washing machine was recently placed in the gymnasium to take advantage of the extra hot water available during much of the year.

We were also interested in the possibility of being able to modify the heating system so that it might be used in entirely new ways. In the fall of 1977 we carried out one such modification. With the approval of NASA and the Department of Energy, we extended the ductwork through the west wall of the collector support structure to a newly-built, 6000-bushel grain drying silo. Last fall the school solar-dried all of the 5300 bushels of corn grown to feed the roughly 600 hogs that are raised and marketed annually as part of the school program.

Construction and Maintenance

The solar heating system was constructed by the same firm that erected the gymnasium. This facilitated the dovetailing of work and communication among the various construction subcontractors. However, we felt there was one problem area in terms of communication--an inadequate interaction between the construction contractor and the solar hardware manufacturer, Solaron, Inc., who designed most of the system.

For example, the 100 ft. manifold that takes hot air from the collector was painstakingly fabricated from insulated sheet metal and then assembled at the site. After assembly, the ductwork leaked at most of the joints, and the contractor had to seal all joints with a silicone caulk. A phone call to Solaron, who drew the blueprints showing ductwork sizing, would have informed him that he could have used lightweight, prefabricated ductboard tubing at a lower cost and a considerable saving in time. Another example--air diffusors, rather than deflection registers, were mistakenly installed in the gymnasium. Although Solaron's blueprints were ambiguous on this requirement, a letter or a phone call would have quickly cleared up the matter. Moreover, such communication should have been made since diffusors, which would spread air around the top of the building rather than direct it to the floor where it is needed, clearly did not make sense.

Because it had to be so large, much of the ductwork associated with the air handling system was hand fabricated from sheet metal. This proved to be time-consuming and expensive. Motorized dampers also had to be custom made; the long lead times required by the manufacturer were not anticipated, and the project was delayed accordingly. The motor mechanisms for the motorized dampers were installed after the ductwork was assembled. Because we could not actually see them, we had difficulty telling whether or not the dampers had closed properly. In one critical instance, one had not. Air (600 cfm) was mistakenly allowed to flow through the collector and past the air-water heat exchanger when the system was heating from storage. During the first really cold night of the winter it took only a few hours for this collector-cooled-air to freeze and rupture the heat exchanger. No serious damage resulted, fortunately, and the damper was adjusted properly by cutting open the ductwork so that a visual inspection could be made during adjustment. We suggest that motorized dampers be adjusted while ductwork is being assembled to guarantee a tight seal. It is important to emphasize that this accident was not to the collector itself. Although the heat exchanger was out of operation until needed repairs were made, the collector and the building heating system continued to function satisfactorily.

The system has required virtually no maintainance during the past two years. Motorized dampers have been adjusted and lubricated, the 3 hp air handling motor has been serviced and one drive belt replaced, and this summer the air filter will be cleaned and the heat exchanger flushed out with a descaling compound.

If We Were to Do It Again

The Scattergood solar heating system has performed well since it was started up. During the two heating seasons of its operation it has supplied about 85% of the heating needs of the gymnasium, more than had been projected in the design. Nevertheless, the solar portion was almost 40% of the cost of the entire structure, and one is compelled to ask, "Is it worth building a $94,000 solar unit in order to save $1,000 worth of propane each year?" Perhaps this is not a fair question because of the pioneering nature of the project. We do feel, however, that we have learned some lessons that would result in changes affording a more cost-effective heating system if we were to do it again.

- During the construction phase of the project, we would make sure that each subcontractor knew exactly what he had to provide and what would be supplied by others. In addition, we would insist that a clear and well-used line of communication be maintained between the designer (in our case, the solar hardware supplier) and contractors involved in the actual construction. Money and time were wasted because this line of communication was not actively used.

- The collector array would be smaller. We now know that the heat-loss coefficient is considerably less than we had originally estimated. Even if the coefficient were to rise with increased building use, a collector area of about 1500, rather than 2500 sq. ft. would probably be adequate. A smaller array might permit design flexibility and allow cost savings disproportionate to the size reduction. We feel that in our case, at least, there was a diseconomy of scale; we paid a penalty for bigness. For example, the array took over twice as long to build as had been anticipated based on smaller assemblies. The large ductwork was slowly assembled from sheet metal and required the sealing of every seam and joint with a silicone caulk. The expensive, custom-fabricated air handling unit was delivered two months later than scheduled. Because of its size, the rock storage box had to be made of 8-inch reinforced concrete and placed outside of the building.

- We would try to design a system that would use as much as possible off-the-shelf, rather than custom-built components. This might require two separate arrays, each with its own air handling unit servicing a common manifold. Such a design would require little more ductwork than used presently, and might permit the system to operate in two modes simultaneously, such as drying grain and heating the building; or perhaps only half of the system could be used to heat water in the summer.

- We would try to place the storage system inside the building or we would have a much better insulated rock storage box. During the 1977-1978 heating season, 39 x 10^6 Btu, or 35% of the energy sent to storage, was unrecovered. This amount represents 39% of the total energy used for space heating. If less of this heat were lost, or if it were lost to the building, rather than to the environment, a significant increase in efficiency of the overall system would be achieved.

- The use of eutectic salts, rather than rock, as a storage medium would be seriously considered. Although expensive, eutectic modules require only a small fraction of the space needed by rock. Space reduction would be important if the storage system were to be located within the building.

There is an even more significant factor in the case of Scattergood School. Most of the buildings are heated by forced air. Eutectic modules charged by the collector might be transported to other buildings and used as a supplementary heat source during the spring and fall, when the recreation program is outdoors and there is a large excess of heat from the collector. The cost effectiveness of this approach has not been closely examined, but it would certainly be considered if we were to do the project again.

In summary, although we are satisfied with the performance of the existing solar heating system, if we were to do it over again we would make changes that should improve the efficiency, flexibility and cost-effectiveness of the structure.

Solar Heating and Cooling of
Mount Rushmore National Memorial Visitor Center

C. W. Chiang

Key Work Abstract

Application--heating and cooling solar system.
System Type--active hydronic with absorption cooling.
Collector Type--Flat Plate Liquid.
Collector Manufacturer--Lennox.
Collector Area--2,000 square feet.
Storage Capacity--3,000 gal. steel tank.
Building Load--6.1 x 10^8 BTU/yr.
Building Owner--National Park Service, Department of Interior.
Architect/Designer--Spitznagel Partners, Inc.
Contractor--South Dakota School of Mines and Technology.

INTRODUCTION

This project is a solar retrofit project of Mount Rushmore National Memorial Visitor Center at Keystone, SD, where over two million tourists visit each year. The Visitor Center has a total space of approximately 6,000 sq. ft. The solar system is designed to furnish approximately 45% of heating for the total facility, and approximately 53% partial cooling of the 2,000 sq. ft. observatory room. There are a total of 112 panels of Lennox liquid circulated collectors, each 3 ft by 6 ft in dimension, with a gross surface of approximately 2,000 sq. ft. The unit cost of the collector is about $13.00 per sq. ft. Collector panels are mounted in 5½ rows on the roof of the Visitor Center owned by National Park Service of the Department of Interior. The building was designed by the Spitznagel Partners, Inc. The project consists of four team members with South Dakota School of Mines and Technology as program manager; the Spitznagel Partners, Inc. as construction manager and designer; Honeywell as a collector supplier; and the Mount Rushmore National Memorial as the owner.

DESIGN PHILOSOPHY

The design of the system was a cooperative effort involving primarily Drs. Don Hopkins, C. W. Chiang, and R. L. Pendleton of the South Dakota School of Mines and Technology; Mr. D. L. Rosenstein and Mr. K. Schmidt of the Spitznagel Partners, Inc.; and Mr. G. L. Merrill of Honeywell Energy Systems Center.

The first design decision was to install collectors which used liquid rather than air as the heat transfer fluid. There were three factors which indicated that this was the best choice: (1) A liquid medium would integrate easily with the existing system by simply installing a heating coil in the furnace air duct. The liquid could be circulated directly from the collectors to the heating coil for optimum transfer without additional blowers. (2) There is a need for extra air-conditioning in the observatory room which could be met by solar activated lithium bromide absorption refrigeration units. Air collectors do not produce high enough temperatures to activate these units. (3) The limited space to mount the collector array required collectors with high efficiency and air collectors are generally less efficient than liquid collectors.

Some of the more important design decisions were determined according to the following conditions: (1) The collector area (active area of 1720 sq. ft.) is the maximum which can be fit on the roof and allow enough spacing to avoid shading (5% of total in December). This is also based on the actual total fuel consumed in FY 1975 or 8,721 gallons of No. 2 oil, assuming a heating value of 140,000 BTU per gallon and a furnace efficiency of 50% due to the age of the furnace and an altitude of about one mile, the total annual heating load of about 6.1×10^8 BTU's is determined. (2) The three 3-ton Arkla units are the maximum number which can be operated with the given collectors. (3) The 3,000 gallon storage tank is a compromise between performance and available space. (4) The solar heat coil, effectiveness = 0.538, is the largest reasonable coil which can fit into the existing furnace duct. (5) The angle at which the collectors are placed is a combination of the orientation of the roof, a 45° angle relative to the roof for ease of construction, and a need for solar collection both in winter and summer. The optimum angle for this particular application was not determined, but other simple models show that the performance is probably only 2% less at this angle than at the optimum of about 55° in winter. The angles used here favor the air conditioning application. (6) The control system is designed to use solar heating or cooling first and then the current conventional system as backup. It will be possible to air condition and solar heat during the same day, even though this feature is not in the computer model for simplification.

Solar energy system calculations were based on climatological data for Rapid City supplied by the National Oceanic and Atmospheric Administration (NOAA). The climatological conditions at Mount Rushmore (25 miles southwest and 2,000 feet higher than Rapid City) are expected to be more favorable due to the altitude and lack of pollution in the air, making these calculations conservative.

TRNSYS system developed by the University of Wisconsin modified by South Dakota School of Mines and Technology was used to simulate the solar system. The climatological data for 1971-74 was used for the simulation model. The TRNSYS program used here should enable the user to write a workable transient simulation program with a minimal knowledge of computers. TRNSYS has built-in checks to spot obvious errors such as calling for an input from a non-existent unit, failure to specify initial conditions, etc. Other errors such as improper conversion of units, crossing the temperature with the flow rate, etc., can be very difficult to spot. In this case, the user must know enough about the system to realize that the answers are nonsense, even though the computer processes the numbers without printing an error message. If the program fails to produce answers which converge within the specified tolerances in the specified number of iterations, the user has recourse to decreasing the time step, raising the tolerances or number of iterations, or sticking the control units after fewer calls in one time step. When these fail to produce convergence, then it is essential to have familiarity with FORTRAN and general knowledge of iterative techniques to trace and correct the difficulty.

The flow rate is calculated on the basis of .3 gpm per collector panel specified by the supplier.

The 3,000 gallon storage tank to provide reasonable heat storage for heating and reasonable period of continuous cooling is housed above the ground with three 3-ton Arkla units, heat exchanger, pumps, and all controls in a building connected to the Visitor Center on the east side. This selection gives ease in installation of piping, storage tank and other equipment. The length of piping is minimized.

OPERATION OF THE SYSTEM

The whole system was completed in September of 1977. First the system was tested with pure water in the solar collector loop for about a week, and the system seemed to function properly and was then charged with ethylene glycol for continuous operation. The presence of air bubbles in the system was a constant problem. The pressure build-up due to the air bubbles was alleviated by frequent venting on the top of the roof. The system pressure could be in excess of 70 psig. The air venting could be as frequent as once a week.

The winter of 1977 in South Dakota was one of the severest ones experienced. The National Park Service was quite happy with the saving of many gallons of oil. The system apparently functioned well in solar heating. No major problems were detected except that the main system pump was always running for all modes of operation. Nobody knew exactly how well the system was functioning until the early part of May of 1978 when IBM contracted Site Data Acquisition System (SDAS) to begin to produce some computer printouts. Quite a few anomalies were picked up by the SDAS such as the main system pump was running all the time; the sequence of operations was different from what was originally planned; solar and auxiliary heating have the same control setting; energy from storage is not always being taken to meet the heating load, etc.

The Arkla cooling units were started after mid-July of 1978. The cooling system was never utilized to its full capacity due to the fact that the control of the system was not completely under control. Adjustments and corrections are still being made by the Honeywell people. At the end of May, 1979, Honeywell sent two people to the site for over a week to redesign and rewire the control system. The objective was to correct all anomalies and organize the control system with indicator lights. Each indicator light, when lit, will indicate which zone is calling for heating or cooling. It is expected that the system will be improved in both heating and cooling.

PROBLEMS ENCOUNTERED AND SOLUTIONS

The major problem is the air bubbles in the system. As explained in the operation of the system, constant venting with frequencies as much as once a week to prevent a buildup of temperatures and pressures was necessary. The main pump was originally designed at the flow rate of 30 gpm. It was felt that the higher flow rate could solve the problem of pressure buildup or air bubbles problem. A larger pump was installed with the flow rate of approximately 48 gpm. This seemed to solve the air bubble problem. The frequency of air venting has drastically reduced. Another problem encountered was one transformer was struck by lightening on August 14, 1978. Because of this the main pump was stopped so that the solution in the cooler loop was overheated. Most of the ethylene glycol solution was lost. It took more than two weeks to repair the transformer, recharge the system and get it back into operation. This situation rarely happens.

At the end of December 1978, a phenomenon of thermosiphoning occurred to the system, apparently due to a severely low ambient temperature (about -35°F). The cold antifreeze solution in the collectors on the roof flowed back to the main heat exchanger inside the mechanical room at about 12 feet below the roof. As a result the cover plate was fractured and two ruptured slits of about one inch in length appeared on two tubes of the tube bundle inside the heat exchanger. Antifreeze leaked from the collector loop in the shell side of the heat exchanger into the tube bundle through the ruptured slits on two tubes and also leaked to the outside through the fractured cover plate in a large amount. It took almost one month to reorder a new cover plate, to braze the two ruptured slits and to refill the system with antifreeze. To prevent any future similar thermosiphoning, a check valve was installed into the piping such that any back-flow due to thermosiphoning may be avoided.

It is interesting to review the temperature excursions of the inlet and outlet temperatures of the main heat exchanger as shown in figure 1, which was deduced from SDAS results. (December 1978 monthly report put out by IBM through DOE) Note that the temperature sensor, T103 on the collector side, indicated at, or below 32°F (32.406°F is the minimum possible reading of this sensor) for the major part of both days of December 29 and 30 of 1978. Since the main heat exchanger is housed inside the mechanical room and is about 12 feet below the roof, this gave a clear indication of the thermosiphoning. The temperature sensor, T153 on the heating coil side, showed a drastic decrease in temperature in the afternoon of December 30 and reached a possible minimum about 10 PM as indicated in the figure 1.

SUCCESSFUL COMPONENTS OR PROCESSES

Aesthetically the Park Service people were worried that the presence of solar energy heating project might distract from the main attraction. Since the installation of the collector panels, the visitors apparently are not aware of the presence of collector panels on the roof of the building. This seems to satisfy the Park Service. Comments from people who have seen the collector panels are good. Aesthetically, they blend in very naturally with the building.

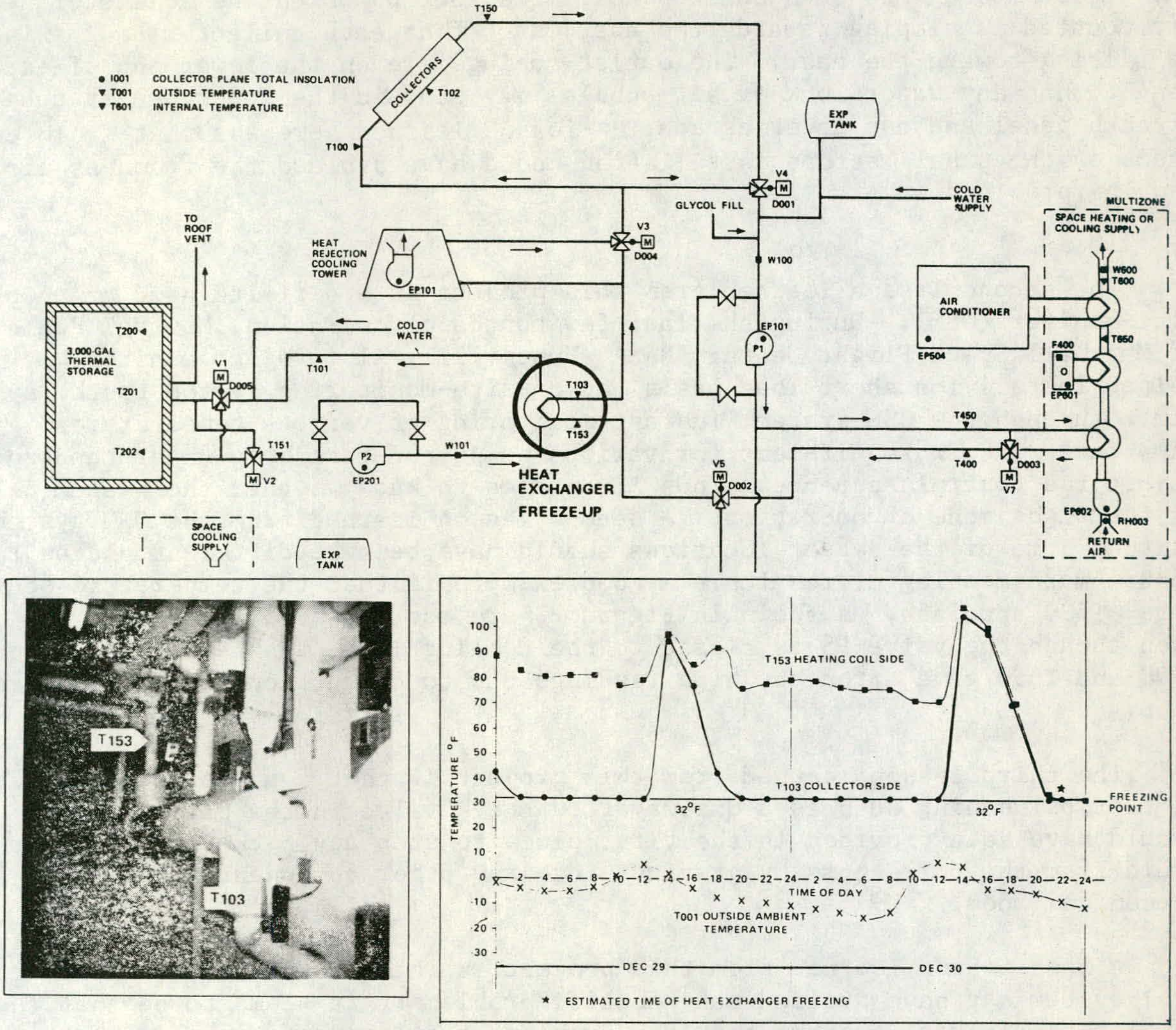

Figure 1

COSTS

All the costs have been within the proposed budget. There were no cost overruns during construction. At this point there is still some money left in the project for the evaluation period, mostly for emergency repairs and some minor modifications of design and analysis.

LESSONS LEARNED

From the major problem of frequent air venting encountered in the operation of the system, the biggest cause may be the wrong locations of the inlet and outlet tubings to each solar panel. The roof on which the collector banks are mounted is sloping towards the east, such that each collector bank axis is tilting toward the east. The outlet tubings are on the lower end of each panel, thus any vapor lock or air bubbles may stay in the upper header tube of each panel and can never escape. A lesson learned here was that a close check of the panels before installation could have avoided the frequent air venting problems.

The second lesson learned from this project is a definite need of an on-site-monitor (OSM). During the last few months of operation, Mr. Val Fogle of Marshall Space Flight Center, NASA, Huntsville, Al (project monitor) helped install (on short loan basis) an on-site-monitoring system to the system. Through the OSM system, instant monitoring of various temperatures flow rates, power requirement for various pumps and fans help understand and adjust the control sequence. Thus it enables to know whether the system is in the right mode of operation. A second lesson learned from the OSM system is that some of the sensor locations should have been at different places to ensure more meaningful results. A good example is that the temperature sensors, T500 and T550, as shown in Figure 2, are too close to the valve V5. Even though the valve V5 is closed to the cooling loop, the temperatures, T500 and T550 gave erroneous high readings due to conduction from the heating loop.

The third lesson learned from this project is that a positive prevention of thermosiphoning such as a one-way flow check valve in the piping system should have been provided in the first place to stop any back-flow of cold fluid from the collectors by gravity, into any other components inside the mechanical room.

A last lesson learned from this project is that a further simplified control system may have avoided many control problems. It seems to be that the simpler the control system, the less problems that are apt to occur.

PERFORMANCE EVALUATION

i. Introduction

The performance evaluation was the result from two monthly performance reports, one December 1978 and one February 1979, based on the monitored SDAS data and put out by IBM people through DOE. From the reports, the performance of the solar system was far from the designed annual load of 45% for heating and 53% for air conditioning requirements for the observation room. It is understandable that as long as the control problems linger and are not fixed, the performance evaluation would not represent the true capacity of the system except to provide the anomalies of the system. It is expected that the performance will be drastically improved as soon as the control system is behaving.

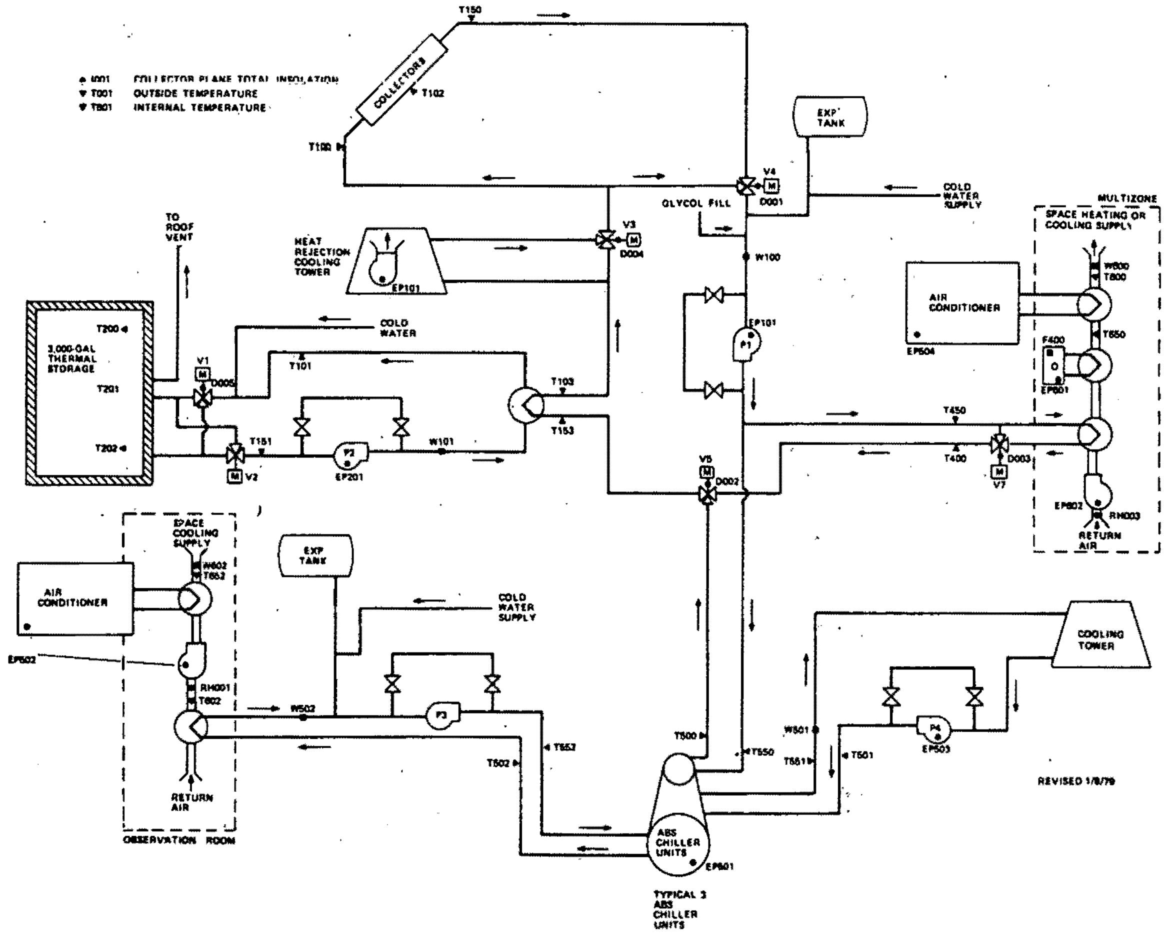

Figure 2

From December 11 to December 30, 1978 operation of the system showed marked improvement over previous months in that the periods of solar collection and energy storage coincided with periods of solar energy availability. This was due mainly to the control modifications made during the last week in November. The improved operation of the control system continued through February of 1979.

ii. Weather data

During December of 1978 the measured averages for ambient temperature was 20°F which was 6.7°F below the long-term average temperature. The measured average daily insolation in the plane of collector was 1033 BTU per sq. ft., which was 4% above the long-term average of 996 BTU per sq. ft. However, during February the measured averages for ambient temperature was 25°F which was one degree above the long-term average of 26°F for the Rapid City area; the measured average daily insolation in the plane of the collector was 1316 BTU per sq. ft. which is identical to the estimated long-term average.

iii. System Thermal Performance

The total solar energy incident on the collectors amounted to 53.45 million BTU's during December 1978. The system collected only about 20% of total incident energy. However, it is significant to note that the collected amount was collected with the collector operating an estimated 55 hours during the entire month due to weather and control problems.

During the month of February of 1979 a total of 63.56 million BTU's of incident solar energy was measured in the plane of the collectors. The system collected about 27%. During the time the system was operating, a total of 41.94 million BTU's was incident on the collector array. This represents an operational collector efficiency of 42.3%. Clearly the performance of the month of February was improved, resulting from correction of the major system control problems. The system operated in the collector mode for a total of 118 hours with 34 hours of directing heating from the collectors, 84 hours of storing energy and 81 hours of supplying heat from storage. For all periods of operation, the collection mode occurred during the daytime hours while heating from storage occurred during night time and early morning hours, and thus it is consistent with the design philosophy of the system.

As soon as the solar system is operating normally, the future performance evaluations from SDAS will truly assess and evaluate the performance of the system in terms of collector efficiency, energy savings, etc.

OTHER KEY ITEMS OF INTEREST

The IBM contracted Site Data Acquisition System (SDAS) and its associated On-Site Monitor (OSM) have been in operation for months. The Figure 2 of the whole system shows location of sensors as well as various components of the solar system. Daily printouts and plots of SDAS have been supplied on request to analyze the various anomalies of the system. In particular, the OSM has been a great help, as explained in the previous section.

INVITED PAPERS
ORLANDO, FLORIDA

"CERTAINTY AMIDST MANY QUESTIONS"

Introductory Remarks By

G. Barry Graves

Director, Southern Solar Energy Center

Atlanta, Georgia

For some time we have seen major controversy over and questions about the availability of conventional energy supplies and their pricing. I was personally appalled, as I expect many of you were, when recent national polls indicated that large segments of the public were not really convinced of the reality of our energy shortage.

Yet the following simple statement is fact: It is certain that our oil and natural gas supplies are limited and that they are being rapidly depleted. President Carter's address last evening (July 15, 1979) made this point in a very convincing manner. I hope that many Americans were listening!

It is true that we can benefit greatly from an immediate adoption of conservation measures, and this is essential to be fair to future generations. We also need to continue the search for additional conventional resources, if only for their use as liquid fuels and chemical feedstocks. Synthetic fuels, coal, and other sources can provide relief for another few decades, although they will be subject to increasing prices and ever-present environmental concerns. But let us consider the time element. This is, or should be, a matter of urgent concern. While we may be in error, plus or minus, about the availability of yet undiscovered oil and fossil fuel reserves, considering the schedule necessary to make a transition we are already in a dangerous situation. Consequently, it is imperative that we begin NOW to exploit solar and renewable energy sources.

Transitions of the type we face have historically required lengthy periods—say 20 to 40 years—for significant impact. It is easy to see why. Energy is an integral part of our daily lives. Consider the changes needed in homes, office buildings, industrial processes, and transportation methods—even if we knew exactly what to do. Changes to structures, whether through retrofit methods or replacement, will take many years. The industrial impact is equally severe. And we will probably have to develop a much improved "system approach" for community planning and transportation system design (the present methods of accomplishing this are, at best, questionable).

The conclusion, is that we must begin to make steady, realistic progress in a transition to solar and renewable energy sources. These sources can supply a significant fraction of our energy needs, but the timetable is up to us. We do need to move out of the "demonstration" phase into practical, economically feasible applications as quickly as possible.

You—the system designers, architects, builders, industrial engineers, planners, government officials, and many others—are the key to making this happen. We know that this conference will show some of the very real progress which has been made through the DoE Solar Demonstration Program. We also hope that it will help you see how you can be effective in applying solar system designs which will work reliably, and with good economic performance, in the future.

It is clear that much solar technology, especially passive design, hot water systems, and moderate temperature systems for all types of applications, can be applied now. Of course, there will be improvements in equipment and design techniques for these systems, as there are in any field, but the basics are here today and future advances will not make them obsolete. Time is no longer on our side in terms of available energy supplies or their cost. Therefore, I hope that you will take a lead role in your professional group, community, or company to apply solar where it is feasible today.

With recent tax incentives, more realistic oil pricing, and other motivators, we will see a dramatic increase in the number of opportunities for solar applications. Your support and dedicated action as designers, manufacturers, installers, municipal planners, and other key individuals will be vital factors in helping relieve our country's energy problem. I am certain that the staff members from DoE, the Department of Housing and Urban Development, the National Bureau of Standards, NASA, and other organizations which are providing speakers and session chairmen today will endeavor to provide information and assistance to any of you at the conclusion of the conference.

As head of one of the four regional solar centers—the Southern Solar Energy Center, located in Atlanta—I would like to comment that we look forward to working with you in the future. Thus far, we have been in the planning phase, but expect to enter the operating mode as a DoE Contractor at an early date. We are beginning our activities in the areas DoE has selected as most suitable for early "commercialization." The initial programs are concerned with passive buildings design, solar hot water, industrial process heat, wood combustion, and limited efforts toward small wind systems. We expect to serve as a catalyst to help the free enterprise system function at its best. Much of our work will be in information dissemination and in a limited number of pilot projects. One of the sessions tomorrow is devoted to further discussion of these activities and will be valuable to us as means of hearing your views and suggestions.

We look forward to meeting and working with you. Thank you for your attention during these introductory remarks.

DESIGN OF AND EXPERIENCES WITH ENERGY CONSERVING HOMES

by

Frank W. Wilkins and Glenn N. Reid

ABSTRACT

This paper is an overview of a concept in building houses that conserve rather than waste energy unnecessarily. It is a marriage of the theoretical design analysis and the practical experiences gained from four such houses that were built in Columbia, Maryland. The rapidly rising cost of energy and the growing scarcity of fossil fuels is necessitating a basic change in the way houses are being built. This paper presents a comprehensive method of designing houses that remain aesthetically appealing while at the same time reducing the heating costs by 70%. This dramatic savings is accomplished by combining a sophisticated insulation package with a solar heating system that minimizes fuel costs.

Major design parameters of the insulation package and the solar heating system are discussed. These include sizing the collector array to be most economical, selecting the storage tank size and methods of integrating the solar system into the architectural design of the house. Charts show the expected monthly savings due to the solar heating system.

The progress of this solar, energy conserving development is traced. Emphasis is placed on the practical problems that may be encountered in bringing the design to a finished product.

INTRODUCTION

As a result of the rising costs of oil and natural gas, it is becoming more and more important how houses are designed and built. The technology is now readily available to build homes--not expensive custom models but large numbers of standard development homes--that use only 30% of the fuel that similarly sized houses consume. The market for these homes is now emerging and will continue to grow as the general public becomes more aware of:

1. the monetary impact from the rising costs of monthly utility bills and

2. the psychological impact from the spectre of fuel shortages that have caused schools and businesses to close.

The energy conserving home is a home that is built to minimize its energy needs and receive much of the energy it does need from the sun. The focus of this paper is the design, construction, and marketing of four of these homes that were built in Columbia, Maryland, during the winter and spring of 1977.

DESIGN PARAMETERS

A. Site Planning - The design of a solar heated home starts in the site planning. There must be a surface that is facing as near south as possible. Thus, the lots and the houses must be matched so that the roof lines can be properly orientated. Generally, 5° west of south is the best orientation, but there isn't a serious degradation in performance if the collector is within $\pm 30^{\circ}$ of south. Thus, there is a certain degree of flexibility available in positioning the homes on the lots.

B. Insulation Package - By far, the most important aspect of the energy conserving home is the insulation package. This will determine how much energy the house needs to maintain the desired comfort level. Also, it determines the size of the more expensive solar heating system. Thus, a well insulated house results in not only a lower fuel bill, but also a considerably less expensive and more effective solar heating system. Because of the high initial cost of the solar system, it should not be used unless the building is well insulated.

Typically, the heat losses in a residence occur in the following areas:

1.	Windows/doors	30%
2.	Exterior walls	15%
3.	Ceiling	15%
4.	Floor	5%
5.	Infiltration	35%

To minimize the losses from these areas these four homes had the following[1]:

1. double insulated windows
2. 3 1/2 inches of fiberglass (R-11) in all exterior walls
3. 8 inches of blown cellulose (R-30) in ceilings
4. foundation insulated
5. polyethelyne vapor barrier on all exterior walls with a 2 inch overlap
6. extensive use of caulking in all areas where infiltration could occur.

These measures were found to reduce the energy consumption by 25% over the same models using a regular insulation package. This reduction in energy load involved no new technology, no sacrifice to aesthetics, and no great cost. The entire package could be expected to pay for itself in reduced utility bills in five years or less.

C. Solar Heating System - These homes were designed to receive 60% of their yearly heating and domestic hot water needs from a solar heating system that was integrated into the conventional heating system of the house. The solar system was not sized to provide all the house's heating needs because of the large size of the collector array that would have been needed. There are occassionally long, cloudy periods of little or no sun. It is not practical to size the collector to meet

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NOTE[1]: "Ryan Standard Energy Package" Ryan Homes, Pittsburgh, Pennsylvania the house's needs during these periods. To size the solar system to be most economical, Figure #1 can be used[2].

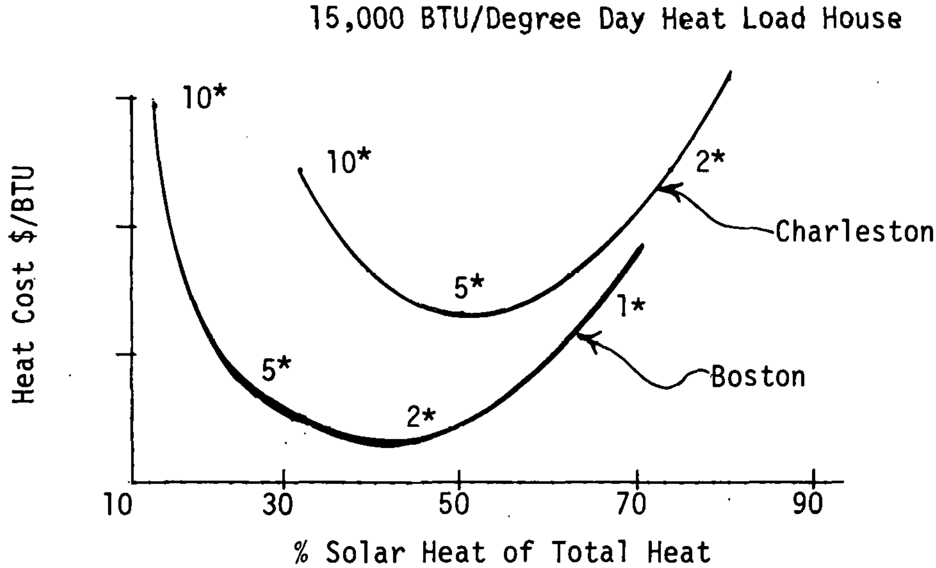


Figure #1 Influence of Collector Size on Cost of Solar Heat

This shows that the optimum size (by cost) of the solar heating system occurs when it is supplying 50-60% of the home's needs. To use this graph to determine the optimum collector area, pick a value of A from the curve and determine the heat load (space heat and domestic hot water) of the house. The heat load can be put in the proper form by using the following equation:

$$Q_s = 0.75 \times 24 \times \frac{\text{Design heat loss rate (BTU/hr)}}{\text{Temp. difference between outside and inside for design conditions } (^{o}F)}$$

NOTE[2]: LOf, G and Tybout, R, "Cost of House Heating With Solar Energy", Solar Energy, 1972.

*Values of A used to calculate area of collector

The area of the collector is then determined by:

$$\text{Area} = \frac{Q_s}{24 \times A} \quad (ft^2)$$

where A = 1.5 to 2 for optimum cost benefits.

This value can be used as a first approximation as to the area of the collector that would be most economical for a building. The actual percentage of energy that a collector this size would provide has to be determined using a much more complete mathematical analysis that takes into consideration, among other things, the collector efficiency and the local weather data. Normally the collector is located on a south facing roof, but it can also be placed on a vertical wall. The optimum roof tilt for the collector is about 10^o greater than the latitude. (Washington, D.C., is 39^oN.) The best collector tilt would be 49^o (90^o being vertical). There is not a serious degradation for angles $\pm 15^o$ around this optimum however and architectural considerations on the roof pitch are likely to be more important. The solar system must be made to blend in with the design of the home if it is to be a saleable commodity. Whereas a 45^o roof on a contemporary house may be easy to fit into the home design, it may be a problem putting much more than a 35^o roof on a traditionally styled house.

In this development, for example, the standard roof pitch on the traditional models was felt to be too shallow. It would have been possible to raise the pitch to 35^o to accommodate the collector. However, it was decided instead to put the collector on the roof of the attached garage which could have the optimum pitched roof yet would still blend with the lines of the house. This also provided the opportunity to design a room under the collector, that was made available because of the steep roof, that could act as an additional ammenity for the buyer.

The area of the collector for each of the four homes was 310 ft^2. The collector used was Revere's Combination Roof and Solar Energy Collector, which, as its name implies, is not only the solar collector but also the roof. It is copper sheet bonded to plywood with square tubes attached to the sheet. The square tubes act as the flow passages for the water that is used to absorb energy from the hot copper. The copper sheet is painted black and two pieces of special low iron glass (to reflect as little of the sun's energy as possible) are positioned over the copper.

The energy storage tank is the second big item in the solar heating system. For a system that uses water as the heat transfer medium, such as these, at least two gallons of water storage is needed for every square foot of collector area. There is a slight increase in efficiency if the storage tank is somewhat larger than this ratio. In this system, a 1000 gallon tank was used. The 1000 gallon tank is a standard size that is readily available and relatively inexpensive. It came coated with epoxy on the inside surfaces to prevent corrosion.

D. Heating System--Operation - The homes are equipped with a heat pump, which provide the heating needs when the solar capacity has been depleted. The heat pump and solar collector are integrated into one cohesive heating system by the use of an electronic controller that automatically makes all the decisions as to how the home is to be heated. A schematic of the heating system is shown in Figure #2. The controller can make the proper decisions because, through the use of thermisters and the house thermostat, it knows all the temperatures that dictate how the system operates.

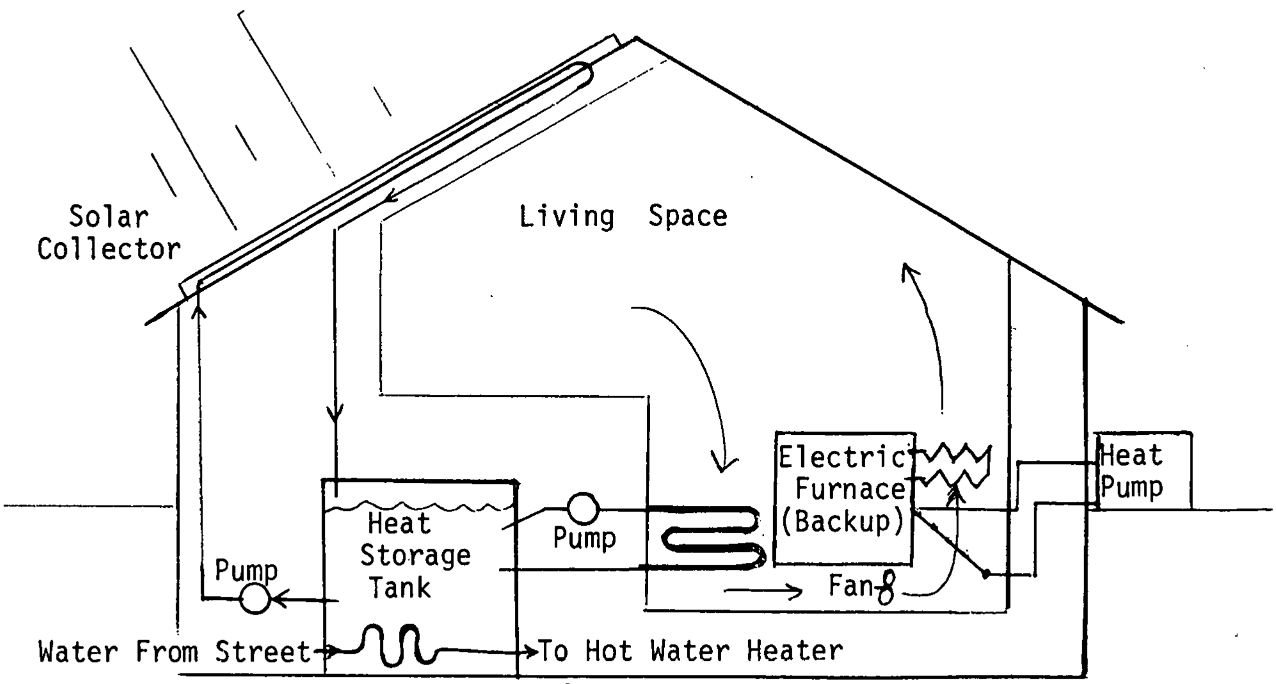


Figure #2 Schematic of Heating System

1. If the collector becomes hotter than the water in the storage tank, it turns on a pump and circulates water from the storage through the collector and back to the storage tank, thus collecting energy. When the collector temperature cools down, the controller turns the pump off and all the water drains out of the collector back into the storage tank. Having no water in the collector except during collection of energy is the method used to prevent freezing of the water during the winter.

2. If the house thermostat calls for heat and the storage tank temperature is warm enough (above 90°F) it turns on another pump and circulates the warm water through a heat exchanger located in the forced air furnace duct. At the same time it turns on the furnace fan, thus transferring the heat to the house.

3. If the house calls for heat and the storage tank is not sufficiently warm, it turns on the heat pump and takes the solar heating system completely out of the picture.

The remaining function of the solar heating system is to supply energy for domestic hot water. As can be seen in Figure #2, water comes in from the street and is taken through a heat exchanger in the storage tank where it is heated. It then goes into the standard hot water heater. In this manner the water reaches the hot water heater at anywhere from 85° to 140°F instead of 50°F.

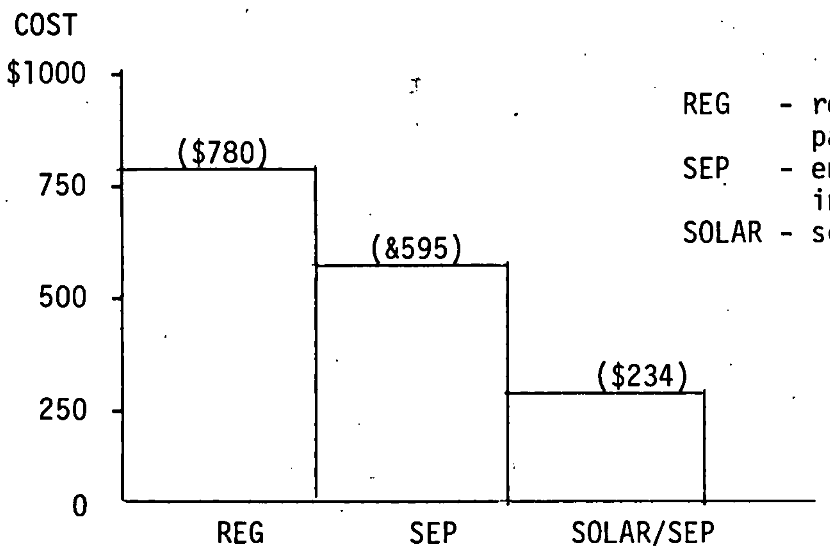
E. Cost Comparisons - These solar systems were designed to provide 60% of the yearly space heat and doemstic hot water needs of the homes. The percentage that the system will supply for any given month (weather permitting) will vary from a low of 33% in December to a high of 100% during May to September. These numbers are determined by a mathematical analysis[3] that has been shown by long term testing to be accurate. Figure #3 shows the monthly contribution of solar energy that is expected on the homes in this development. What this means in terms of savings is shown in Figure #4, which compares the heat and hot water costs of the house with a standard insulation package to the costs associated with the energy conserving homes. Adding more through insulation reduces the energy consumption by 24%.

NOTE[3]: "Intermediate Minimum Property Standard for Solar Heating and Domestic Hot Water Systems, NBSIR 76-1059, April 1976 (Interim Report).

Month	% Solar	Month	% Solar
January	34	July	100
February	48	August	100
March	56	September	100
April	85	October	93
May	100	November	60
June	100	December	33

Figure #3 Monthly Contribution of Solar Heat to Total House Needs

Degree Days	4800
Heat Pump COP	1.9
$/kwhr.	.045



REG - regular insulation package
SEP - energy conserving insulation package
SOLAR - solar energy

Figure #4 Comparison of Expected Yearly Heating Bills

Adding to that the solar heating system, the energy consumption was reduced to 30% of what it was without the energy conservation measures.

The solar heating system cost $10,000, of which 1/3 was for the collector, 1/3 for the installation and the remaining third for the rest of the parts. This price could be expected to drop on future projects, as the labor involved should decrease as the workers become more experienced in the installation techniques. One thing that increased the price of this solar system was not being able to buy in sufficient quantity to get a reduction in the price of the collector. Of the four houses, even though the collector area was the same for each unit, there were two configurations. Had the systems been made exactly the same, the price of the Revere collectors would have been reduced by $500.

To assess what these energy savings and costs mean to the home buyer, a life cycle economic analysis has to be made[4]. This type of analysis considers all the costs and savings that are associated with the solar heating system over its expected life. The analysis looks at the added cost of the system on the mortgage payment, the yearly energy savings, tax advantages and maintenance costs. This is, at best, an educated guess because of the many assumptions as to what will happen in the future. Figure #5 shows the results of this type of analysis. Initially the home buyer pays more for the solar system (the incremental cost on the mortgage) than is saved by the reduction in fuel costs. It is not until the sixth year that the savings per month exceed the monthly costs. The curve in Figure #5 adds all the monthly savings and costs to obtain the cumulative amount saved or lost during the life of the collector. Looking at it this way, it is not until the fifteenth year that there is a cumulative savings from the solar system. After 24 years the solar system has saved the buyer $4800. These numbers do not assume that the system inflates in worth over the years and thus may tend to be conservative. If, indeed, the system's value increased over the years, then the pay back period would be considerably shorter.

Also in Figure #5 is a curve showing the economics of the same system had it cost $8000. This was done to show the impact on solar energy that would occur should the proposed

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NOTE[4]: Ruegg, Rosalie, "Solar Heating and Cooling in Buildings; Method of Economic Evaluation" COM-75-11070 National Bureau of Standards, July 1975.

income tax credit for buying solar heating systems be passed. It will bring the pay back period for the system from fifteen years down to eleven years and mean that the buyer will never have invested more than $600 in the system. If it can be assumed there will be even a modest inflationary increase in the value of the system, it would mean that the buyer would only very briefly lose any money on the system before it started paying for itself.

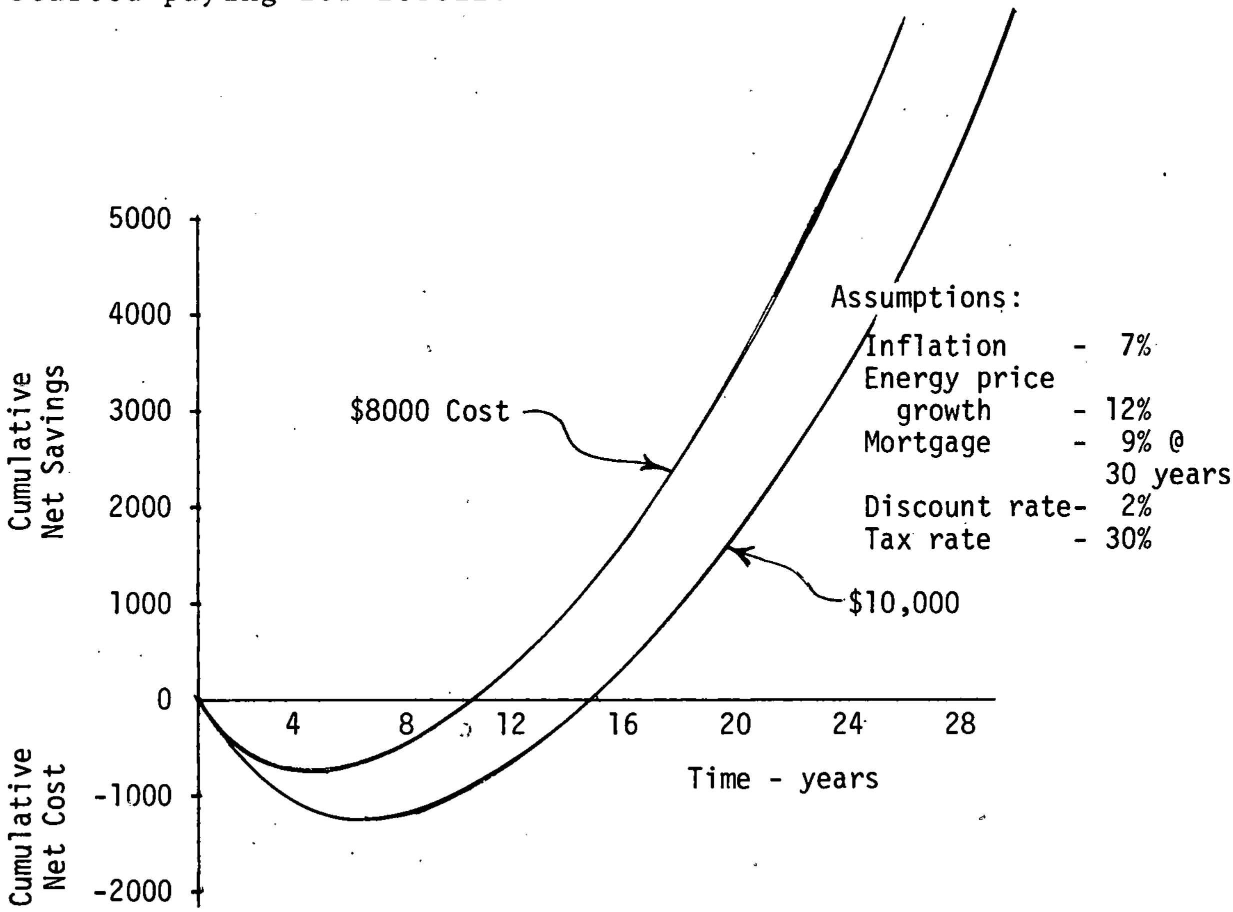

Figure #5 Life Cycle Economic Analysis of Solar Heating System

F. Solar Market - Because this was the first solar tract development in Maryland, it received news coverage not only in local papers but also in such papers as the Washington Post and Baltimore Sun. This, plus modest advertising in two local papers generated a tremendous response that resulted in a constant stream of people through the model home. Because these units were sponsored by HUD, the developer discounted the price of the solar system to $6500. Thus, part of the appeal to potential buyers was the bargain price they would be getting.

Unfortunately for the developer, many of the people coming through the model were exclusively interested in the solar system and didn't have much interest in buying homes. They were also very inquisitive about finding out how it worked. Thus, he and his sales personnel had to learn enough about solar energy to be able to answer questions.

As for serious buyers, though, the first solar house was sold literally minutes after the sales personnel were authorized to start taking deposits for contracts. The remaining three solar homes were sold within three weeks. This is considerably faster than the same models would have been sold had they not been solar heated.

The people who bought the solar homes generally knew quite a bit about solar energy. Their feelings were a mixture of: being a pioneer trying something new, being less dependent on the utility company, conserving energy and making a good investment. In two of the cases, it was not the case of telling them the benefits of solar energy and energy conservation energy and making a good investment. In two of the cases, it was not the case of telling them the benefits of solar energy and energy conservation, but actually going over the detailed calculations of the designers (Applied Solar Technology, Inc.). These, then were very sophisticated buyers who knew what they wanted and were happy to be able to get it.

G. Problems - The houses were built in Columbia, Maryland, which is a planned community. It was an ideal place to build a solar development because the population has a better than average income, are technically inclined (many engineers and other professionals) and are used to innovative things being tried within the community. There is, in Columbia, an architectural review board that comments on the building's appearance. This was the first solar development that was going to be put up for sale to the general public in Columbia and the review board made special efforts to assure that the homes would look nice. It was decided to raise the pitch of the roof on the house somewhat to make it blend better with the steeper pitch of the garage roof. Also, there was concern over how the black collectors would look on the roof and how much flashing there would be around the collectors. These problems took some effort to eliminate but posed no great problem. What did cause a problem was the board's assessment that these homes could not be sold in that neighborhood. It was their feeling that $70,000 was the absolute top price that could be obtained for any house in that area because of the price range of the developments surrounding it. Of the four homes to be solar heated one was to be a large model that would sell for the mid seventies with the solar heating system. The remaining three would be smaller models that would sell close to $70,000.

This assessment caused the developer second thoughts on whether or not to continue the project. As it turned out, the big model was the first to be sold. Soon after, it became obvious that the bigger, expensive model was what most people wanted. The ratio rapidly switched to three large models and one small model. Each of these three homes cost considerably more than was thought possible to obtain in that neighborhood.

This is a good example that a solar heated, energy conserving home will increase the value of the home beyond the conventional equation for pricing. People are beginning to realize that the increase in monthly mortgage costs is somewhat offset by a decrease in utility costs. If the basic house is aesthetically pleasing and meets the desires of the buyers, they will be willing to spend the extra amount needed to buy the solar, energy conserving home.

In summary, solar heated, energy conserving homes that consume only a small fraction of the fuel that they would otherwise need are both practical and marketable. In Columbia, four speculative houses were built by a developer who had previously had no experience with solar heating systems. As an indication of the market, all four homes were sold before they were built.

Retrofitting of an Apartment Building for Solar Heating, Cooling and Hot Water

Gary C. Vliet

ABSTRACT

An apartment building has been retrofitted for solar heating, cooling and hot water under the second cycle of the HUD Residential Solar Demonstration program. The building includes twelve single bedroom apartments on two floors. The conventional HVAC and domestic hot water systems are all electric and the apartments are individually metered.

The solar equipment includes concentrating collectors with the main storage being hot water. Preheated make-up water is supplied to the laundry and apartment electric water heaters. Hot or chilled water is supplied through a two pipe system to (solar) fan/coil units in each apartment. In the heating mode water is circulated directly from the hot water storage vessel. In the cooling mode, hot water from storage drives an absorption unit which produces chilled water for circulation through a small chilled water storage vessel and to the apartment (solar) fan/coil units. The fan/coil units are in parallel with the apartment's conventional electric units.

The system presently is not fully operational, with some modifications being made. Recently it has been fully instrumented for monitoring and evaluation of system performance over a two year period.

1. INTRODUCTION

A grant (H-2772) to perform a solar retrofit project was received from the Department of Housing and Urban Development under the Second Cycle of the Residential Solar Heating and Cooling Demonstration program by the Center for Energy Studies at The University of Texas at Austin in October 1976. The project consists of the retrofitting of an existing all-electric twelve unit apartment building, which is part of The Univeristy of Texas "Gateway" apartment complex at 1600 West 6th Street, Austin, Texas, approximately one mile west of the main campus. There have been several other solar cooling demonstration projects (1,2,3;4) among others, however there are several unique features associated with a central solar heating and cooling system supplying the demands of multiple users each with his own auxiliary system. The complex was constructed during 1972 and has been occupied continuously since February of 1973, the occupants being married students attending The University. There are eighteen buildings in the complex, including a total of two hundred apartments. The buildings are of masonry construction, are two- (or three-) story, have flat roofs and most have adequate access to the sun. The present heating and cooling system for the complex, including hot water, is all-electric with each apartment having its own system, and the apartments are individually metered. Five of the apartment buildings also have laundry rooms with electric water heaters. Thus, each laundry room serves the approximate equivalent of three buildings. Electric use for each apartment in the complex is recorded monthly and the records are maintained by the Office of Housing and Food Service at the University. Electricity is purchased by the university from the City of Austin and each resident is billed by the university.

The building selected for the project (No. 1632) is oriented with the long side rotated approximately 15 degrees clockwise from east-west. This building was selected because of its favorable east-west orientation and because the roof area where the collectors are mounted is not shaded by adjacent structures or vegetation for sun altitudes above approximately 15 degrees. The building is two story and consists of 12 apartments as well as a laundry room at the west end of the building. Apartments are single bedroom, each with 600 ft^2 floor area. The laundry is assumed to serve the equivalent of two additional similar apartment buildings.

The total electrical consumption by month for all twelve apartments in Building 1632 is shown in the second column of Table 1. The variation in consumption by month is a result primarily of the seasonal influence on heating versus cooling loads. Annual data on individual apartments (not shown) show a variation of approximately a factor of two, indicating the different lifestyles of the occupants.

Table 1. Energy Usage for Building 1632

Month	Total Resident Usage MWH/Mo	Base Electric MWH/Mo	Heating or Cooling Electric MWH/Mo	Heating* or Cooling Load MBTU/Day	Heating+ and Cooling Energy Req'd MBTU/Day	Hot# Water Energy MBTU/Day	Total Energy Required MBTU/Day
12-1	10.9	5.8	5.1	.58	.58	.35	.93
1-2	9.9	5.8	4.1	.47	.47	.35	.82
2-3	8.0	5.8	2.2	.25	.25	.35	.60
3-4	7.7	5.8	1.9	.22	.22	.35	.57
4-5	7.9	5.8	2.1	.46	.83	.35	1.18
5-6	8.7	5.8	2.9	.63	1.14	.35	1.49
6-7	11.4	5.8	5.6	1.22	2.21	.35	2.56
7-8	11.7	5.8	5.9	1.28	2.32	.35	2.67
8-9	10.5	5.8	4.7	1.02	1.85	.35	2.20
9-10	8.6	5.8	2.8	.61	1.10	.35	1.45
10-11	6.7	5.8	0.9	.10	.10	.35	.45
11-12	8.7	5.8	2.9	.33	.33	.35	.68

*For heating months the conversion is (WH x 3.41 (BTU/WH)/30 Days) = 0.114; and for cooling months the conversion is (WH x 6.5 (BTU/WH)/30 Days) = 0.217.

+For heating the conversion is 0.114 as above and for cooling the conversion is (WH x 6.5 (BTU/WH)/30 Days x 0.55 C.O.P.) = 0.394. (i.e., 6.5 EER on present system and 0.55 C.O.P. for the proposed absorption system.)

#Assumes 10 gal/person-day for the 24 residents of Building 8, plus 5 gal/person-day for the laundry room which is assumed to be used by the equivalent of three similar apartment buildings (i.e., 72 people); therefore, the equivalent hot water usage of 25 gal/person-day for the 24 residents of Building 8 is assumed.

Since the apartments are all electric, it is difficult to accurately delineate the various loads--space heating, space cooling, water heating, lighting and appliances; however, these loads were estimated based on the monthly utility data, as indicated in Table 1. The base load shown in column three (appliances, lighting and hot water) is obtained by selecting the lowest month usage for each apartment in spring and fall (periods where little or no heating or air conditioning is required) and multiplying by 0.9 for conservatism. The fourth column (heating and/or cooling) represents the difference, and the fifth column is the equivalent thermal load (million BTU/day) on the building using the appropriate factors indicated in the table for either heating or cooling. The sixth column is the energy requirement of a solar system using the appropriate factors indicated in the table for heating and cooling months. The eighth column is the estimate for domestic hot water, which includes residents' requirements as well as the laundry which serves the equivalent of three apartment buildings. The last column is the average daily thermal energy requirement by month of a solar collector array to meet the heating, cooling and water heating needs. It is seen that the large energy requirement occurs for cooling in the summer months of July/August, and is accentuated by the c.o.p. of the absorption cycle used for cooling.

The solar system design and sizing were based on the above thermal load requirements.

2. SYSTEM DESIGN

Collector Array Sizing: There is no insolation data recorded for Austin, the nearest stations being San Antonio and Fort Worth. The data used in the analysis of collector performance was a composite* of meteorological hourly weather data for Austin. Hourly total and direct solar radiation was calculated from hourly cloud cover and type. A comparison of the monthly average results for total radiation agreed well with recorded San Antonio data, and in addition, the daily direct normal radiation levels agreed well with the recent data of Boes et al. (5).

In the preliminary design and selection of components, both a high quality flat plate collector and a concentrating collector were compared. The result was that the concentrating collector resulted in better system economics and was thus selected. This was largely a result of the collection temperature requirements for cooling, where the earlier version of the Arkla Industries 25 ton absorption chiller (WF-300) was assumed.

The concentrating collector selected was the Northrup, Inc., linear Fresnel tracking concentrator mounted in east-west rows on the building. Table 2 presents the daily average collection by month for the Northrup, Inc., tracking linear Fresnel collector, for a 20° tilt and for 200°F and 130°F average collection temperatures in the summer and winter seasons respectively. These average data are a result of hourly calculations using the composite year weather tape. Considering that meeting approximately 65% of the annual load by solar is desireable, a collector array size of 1280 ft^2 was selected. The monthly results are shown in Table 3 where the data are shifted 1/2 month from the data in Tables 1 and 2.

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*A composite year of real weather months was used with specific weather months from different years chosen that were "typical" months.

Table 2. Energy Collection from Northrup Collector, 20° Tilt #

Month	$\bar{T}_a$ °F	T_c* °F	Q_D BTU/day	Q_u BTU/day	η (-)	
1-2	56	130	1239	636	.51	Space & Water Heating
2-3	57	130	1514	830	.55	
3-4	63	130	1828	1066	.58	
4-5	73	200	2009	898	.45	Cooling & Water Heating
5-6	81	200	1903	841	.44	
6-7	86	200	2000	924	.46	
7-8	90	200	2082	1012	.49	
8-9	91	200	1989	967	.49	
9-10	83	200	1887	882	.47	
10-11	75	200	1594	661	.41	
11-12	60	130	1191	631	.53	Space & Water Heating
12-1	56	130	1069	499	.47	

$\bar{T}_a$ - Average ambient temperature during collection period; T_c - Average collector inlet temperature; Q_D - Average daily beam radiation on collector; Q_u - Average useful daily energy collection; η - Average daily efficiency based on beam radiation

#These calculations are for 20° tilt; however the collectors are actually tilted at 25 and 30 degrees. This will slightly increase winter time performance and slightly decrease summer time performance; however the overall performance should be essentially the same.

*Note that the collection temperature was assumed to be 130°F (average) during the heating season months while it was assumed to be 200°F average during the cooling season months. Since the WFB-300 absorption water chiller operates well below 200°F at capacity sufficient for this project, somewhat greater collection will be realized in practice.

The heating and cooling loads for the building and laundry room are shown by month in Figure 1. When the absorption chiller coefficient of performance is accounted for in the cooling season, the resulting daily demand on the collector array by month is shown by the solid curve in Figure 2. The dashed curve in Figure 2 is the daily energy collected for each month by the 1280 ft^2 collector array. One observes slight deficiency during the heating season, some excess (waste) during the spring and fall and considerable deficiency during the cooling season where the solar equipment meets approximately one-half of the load.

Heating and Cooling System: In the preliminary design the Arkla Industries WF-300 absorption chiller was assumed. However after the contract was received Arkla's new 25 ton absorption chiller (WFB-300) became available.

Table 3. Energy Analysis for Northrup Collector*

Month	Daily Required $10^6 \frac{BTU}{day}$	Avail. $10^6 \frac{BTU}{day}$	Def(Waste) $10^6 \frac{BTU}{day}$
1	.88	.73	.15
2	.71	.96	(.25)
3	.59	1.23	(.64)
4	.87	1.04	(.17)
5	1.34	.97	.37
6	2.03	1.07	.96
7	2.62	1.17	1.45
8	2.44	1.11	1.33
9	1.83	1.02	.81
10	.95	.76	.19
11	.57	.73	(.16)
12	.81	.58	.23
% Waste			(10%)
% Deficiency			35%

*Note there is anticipated to be approximately a 10% loss of collected energy due to miscellaneous losses; thus the areas considered reflect these losses (i.e. a collector area of 1280 ft^2 with 10% losses is equivalent to 1150 ft^2 without losses.)

This unit with a mechanical pump, permits operation at temperatures as low as 165°F input hot water at reduced capacity. The maximum (peak) collection during the cooling season is approximately 205,000 Btu/hr which corresponds to a cooling capacity of 9.4 tons. Since the peak cooling load for the building is substantially less than the 25 ton rated capacity, the unit was installed with the reduced hot, chilled and cooling water flow rates which permit operation at the normal (derated) 15 ton capacity. A 40 ton water cooling tower was also installed.

A two pipe system was selected to distribute chilled or hot water to a (solar) fan-coil unit in each of the twelve apartments. These solar fan-coil units are in parallel with the existing DX coil and resistance heating element, with back draft dampers incorporated in both the existing and solar units to permit proper operation when each is activated.

Domestic hot water is produced by circulating through a heat exchanger bundle located in the hot water storage tank. This water is circulated to the water heater in each apartment and also to the hot water heater in the laundry room, where it provides preheated makeup water to each tank during demand.

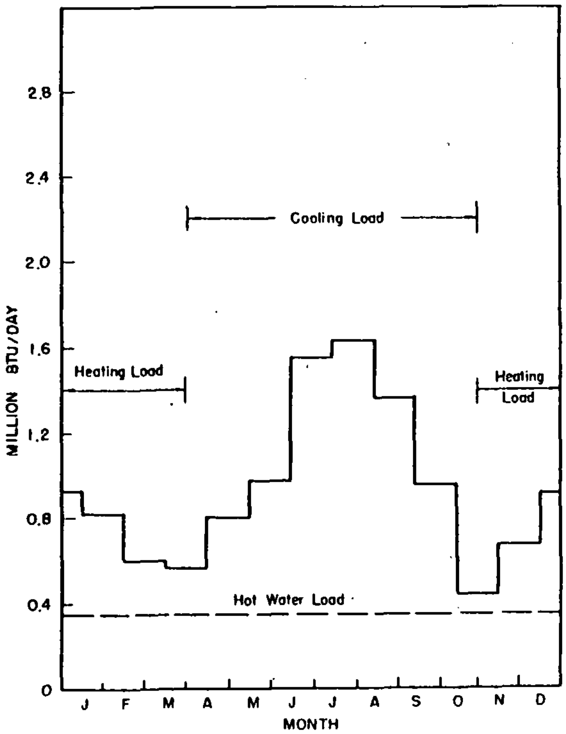

Figure 1. Heating, Cooling and Hot Water Loads by Month for Building 1632

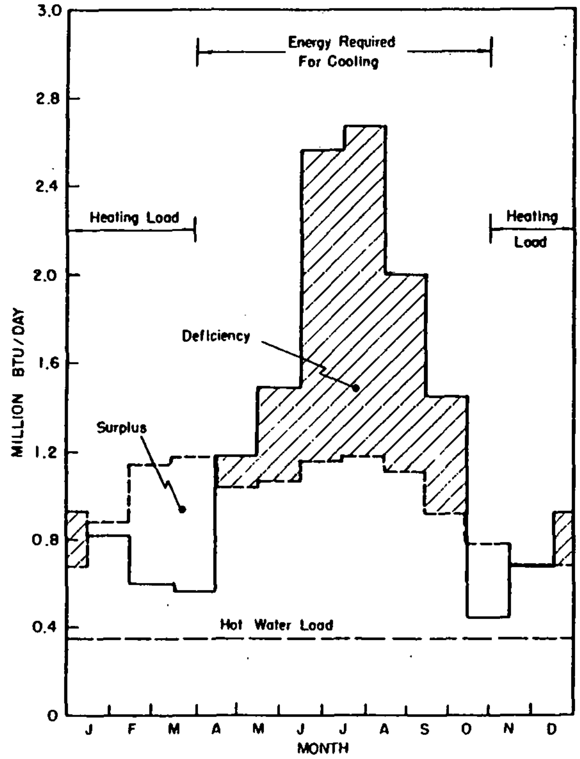

Figure 2. Energy Demand on Solar System and Solar Collection By Month for Building 1632

Thermal Storage: Since the solar cooling system is substantially deficient in capacity during the cooling season, a large chilled water storage capacity is unnecessary; however some chilled water storage capacity is incorporated to provide a buffer between the chiller and the load to reduce cycling of the chiller. The major energy storage is hot water. During peak cooling demand the chiller has sufficient capacity provided the hot storage vessel is above approximately 165°F. The storage consists of a 4740 gallon hot water storage tank and a 500 gallon chilled water storage tank. During the peak heating season the storage capability is slightly less than two days. Because the system (solar) is greatly deficient in meeting the peak cooling system load, during this season storage is not critical. The 500 gallons of chilled water storage results in a chiller cycling time of no less than 1/2 hour during peak cooling load of approximately 10 tons. Each storage vessel is of mild steel construction with a 75 psig rating, mounted vertically and insulated with at least 2 inches of polyurethane foam. An expansion tank is incorporated in the collector loop/hot tank/chilled tank system.

Mechanical Building: A building to house the solar heating and cooling mechanical equipment was constructed adjacent to the east end of the apartment building. The building is 20 x 24 ft^2, with a two story portion to accommodate the large 4740 gallon hot water storage vessel and a one story portion on top of which is located the 40 ton water cooling tower.

Collector Arrangement and Mounting: The 128 collectors (10 ft^2 each) are mounted on the roof in seven banks (six banks of 20 on the apartment building in two rows and one bank of 8 on the equipment building). The back row of collectors is mounted at a 30 degree tilt and elevated (30 in. legs) while the front row is mounted at a 25 degree tilt and low (6 in. legs) to minimize shading of the back row. Each of the seven banks has a tracking unit. Collectors are spaced on 24 inch centers and the rows are aligned with the building. The collectors are mounted on concrete pads to provide a level base for the banks and an equivalent 400 lb per collector to withstand wind loading.

3. SYSTEM OPERATION

Figure 3 presents a schematic of the important components and arrangement of the system.

In the collection mode, pump (P-1) pumps water from the bottom of the hot tank to the collectors (all in parallel) and back to the top of the hot tank. The collector pump is actuated by a differential thermostat sensing the temperature difference between the upper manifold of one of the collector banks and the bottom of storage. Collector tracking is accomplished automatically by sun sensors and the electric motor/cable drive unit on each bank. When the sun is down or the insolation level drops significantly (i.e. a storm) the collectors are driven due east.

The distribution lines to and from the collector are sufficiently insulated to eliminate freezing in our climate; however, the collector receiver tubes are relatively unprotected and freeze prevention in them is prevented by solenoid drain valves on each of the 7 banks of collectors. The solenoid drain valves are actuated by a single thermostat mounted under the receiver tube of one of the collectors when the receiver tube temperature drops below approximately 35°F. Upon actuation, a solenoid valve in the air conditioning water makeup line is closed to prevent inflow of makeup water, and air vent valves on the upper manifold of the collector banks permit drain down to the level of the inlet manifold. Reset of the freeze prevention solenoid valves occurs at 45°F. To prevent overheating in the collector loop an overheat sensor mounted in the upper manifold of one collector bank interrupts the collector tracking if the collector output exceeds 230°F.

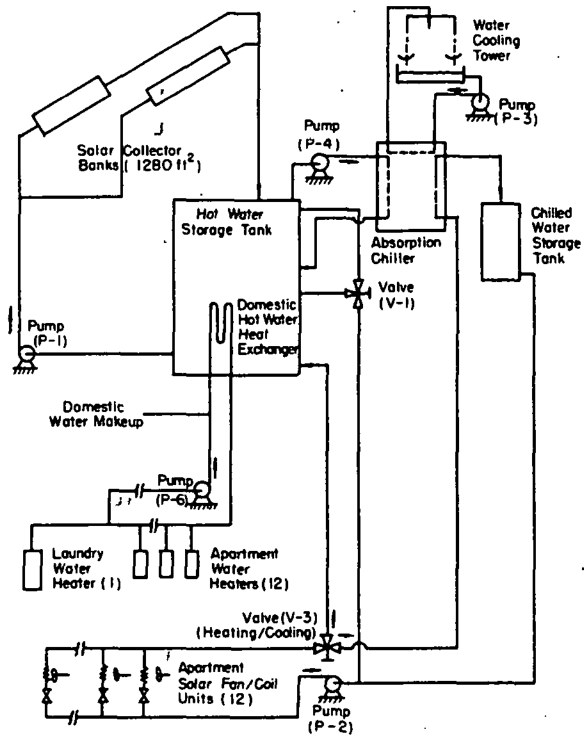

Figure 3. Solar Heating and Cooling System Schematic

Domestic water is preheated in the heat exchanger bundle mounted in the hot tank and is continuously circulated by pump (P-6) out to the apartments and laundry room to be available as preheated makeup water to the water heaters on demand.

A season selection switch for solar heating and cooling is provided with four positions: Cooling, Auto, Heating, and Off. In the Cooling position only chilled water circulation is permitted; in the Heating position only hot water circulation is permitted, and in the Auto mode there will be circulation of either heating water or chilled water depending on the outside temperature, normally set at 65°F. If the outside temperature is below 65° the system is placed in the heating mode (only hot water may be distributed), while if above 65°F the system is placed in the cooling mode (only chilled water may be distributed). The Off position deactivates the solar heating and cooling system and turns control back to the conventional systems in the apartments. The subsequent discussion considers the Auto mode.

When the outside temperature is less than 65°F, valve (V-3) is positioned such that pump (P-2) circulates (hot) water from the hot tank to the apartments. A diverting valve (V-1) directs withdrawal from either the top or middle of the tank, depending on heating load and tank temperature, the purpose being to preserve hot water in the top of the tank if possible. When the outside temperature is greater than 65°F, the system is switched to the cooling mode, with valve (V-3) positioned such that pump (P-2) circulates water through the chiller, the chilled water storage tank and out to the apartments. Under most conditions in the cooling mode, pump (P-4) delivers hot water from the top of the hot tank to the generator of the absorption chiller and back to about mid-level of the hot tank, pump (P-3) circulates cooling water between the cooling tower and the absorber and condenser of the chiller; and pump (P-2) is circulating the chilled water simultaneously. In reality the control logic permits some variation on the above.

When any apartment thermostat calls for heating that apartment's solar fan/coil is activated if the circulated water is above nominally 100°F; otherwise its conventional resistance heater/fan is activated. If an apartment thermostat calls for cooling, that apartments solar fan/coil is activated if the circulated water is below nominally 60°F; otherwise, its conventional electric DX/fan unit is activated.

4. PROJECT STATUS:

The construction (installation) was effectively completed in the late fall 1978. Since that time the system has been operated in all modes; however only for brief periods and not in a completely automatic mode. The reason for this is in part a result of unusually poor weather conditions this winter, but more importantly a result of two significant problems with the system which involve the mechanical contractor. One is a controls problem in which some control wiring was not installed according to specifications, and the other is domestic hot water distribution piping which also did not meet specifications. After some considerable delay, both of these problems are being rectified by the contractor as of this writing, and it is expected that the system will be fully operational in July 1979. Figure 4 shows a view of the installation looking toward the northwest, with the mechanical building on the right.

Figure 4. Gateway Solar Heating and Cooling Project

Several problems have arisen during this project. A recurring problem over the last year has been that of roof leaks. The tar and gravel roof was about 5 years old when retrofit began and was in good enough condition to have been probably satisfactory for a few more years; however with the collector installation and considerable foot traffic, leaks have developed. The problem has been rectified at least temporarily; however it remains a contractural problem. We have not experienced serious problems with collector alignment and leaking as others have reported with the Northrup collectors; however after a rainstorm some collector misalignment has been noted and some minor leaking at the swivels has recently been observed. We have had to replace several tracking motors as well as several shear pins. Northrup Inc. has redesigned the snap connectors on the collector inlets and outlets by incorporating a short flexible hose and this appears to be a good change. The tracking drive unit has also been modified by Northrup; however there still appears to be a weakness in that the shaft is not securely mounted in the motor. The control wiring problem has caused a very serious delay in making the system operational. The installation of the wrong domestic hot water piping (iron pipe instead of copper) has not permitted solar water heating.. Both of these problems are being rectified.

A final comment is in order. The problems that have arisen to date in the installation and operation of the system are not readlly "solar" problems. They revolve around roofing, controls, piping and electrical work. However the problems are definitely related to solar in that the controls are generally somewhat more complex, the installations are somewhat different (collectors mounted on roof) and the technicians are generally not yet familar with the unique influences that solar has on heating and cooling system design.

Subsequent to receiving the contract for this project, funding has been obtained from the Department of Energy and the State of Texas (Energy Development Fund) to conduct a thorough evaluation of the system over a two year period. To date all temperature, flow rate, solar insolation, wind, relative humidity and power sensors have been installed in the system. A data acquisiton system is to be received in late summer 1979, but in the interim a smaller data logging system is being used to monitor the system. This data, recorded on magnetic cassette tape is transferred to disc storage and processed on the Mechanical Engineering Department's Digital Equipment Company PDP 1140 computer system. The data reduction program for this analysis is currently being developed.

The system design, component sizing and projected performance were based on average daily data for each month and did not account for system, weather and load dynamics. A part of the evaluation of the system is to model the system performance using the TRNSYS program. This is now being initiated. Also, since this is one of several similar existing buildings, an evaluation of the solar system performance for the retrofitted building will be assessed in terms of prior energy use patterns in it, as well as ongoing energy use patterns in the other buildings with conventional systems.

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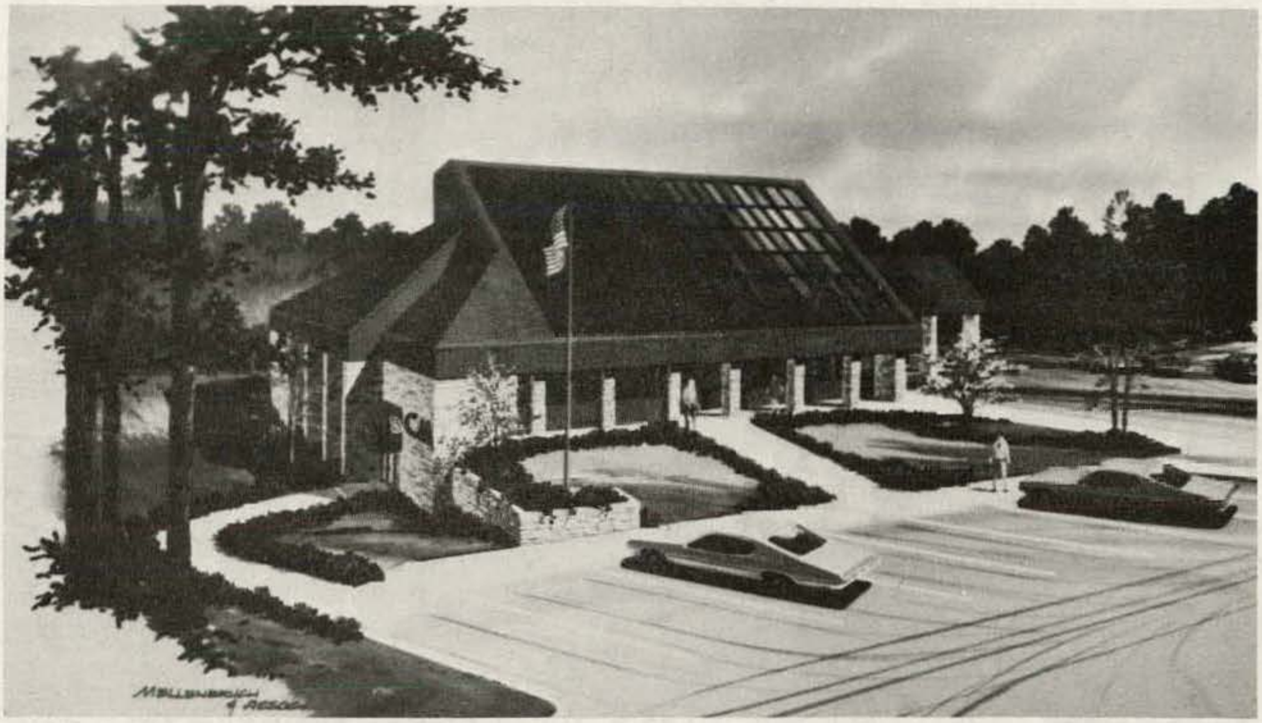

90% Solar Heating & 70% Solar Cooling

Citizens Mutual Savings Association

Ray M. Perkins, P.E.

Citizens Mutual Savings Association is headquartered in Leavenworth, Kansas, some 40 miles west of Kansas City. The association was founded in 1884 and, after numerous growth expansions, had finally outgrown the urban facilities and decided to move to the suburbs. The Board of Directors decided that their new facility should set a precedent for the entire community; that they should be a leader rather than a follower, and therefore, made a decision to incorporate solar heating and cooling into their growth plans.

The design intent, then, was to develop a system that would save energy, utilize solar energy to its utmost, that would be economically feasible and virtually maintenance free. The Owner, in one of the many review sessions, stated that his business was that of saving and the lending of money, and not the operation of mechanical systems. He, therefore, directed the design team to produce a system that would be completely automatic and would not require his attention and service.

The building site is unobstructed by trees and other structures that could cause shadow casting on the solar collectors. Surface parking is provided on the south and east side of the building, thus adding to the potential for diffuse radiation collection. A major thoroughfare passes the site on the west side.

Building orientation is such that the collector panels have a heading of due south and are sloped approximately 40° to the horizontal. Leavenworth is located slightly above the fortieth latitude. There are 120 flat plate panels connected in a series/parallel arrangement with three panels in series and in parallel with all other groups of three. The collectors are Sunworks "Solector" with single glazing and their special coating.

There are two floors in the building, each having 6,000 square feet of area, or a total of 12,000 square feet gross area. Approximately 9,000 square foot is heated and cooled by the solar system, 6,000 on the first floor and 3,000 on the lower level. The upper floor, or first floor, contains all the normal banking facilities, including teller spaces, bookkeeping, vault, and private and general office spaces.

The Energy Code in the State of Kansas requires that new buildings cannot have a heat loss greater than 19 BTU's per square foot of floor area. The Citizens Mutual Building, since it is so well insulated, has a heat loss of 13 BTU's per square foot, considerably below the state code requirement. The roof has a "U" factor of .04 or a resistance of 25, whereas the composite "U" factor of the wall/window is .1526 or 6.55 resistance. The windows, which are double glazed, equal 12% of the total exterior wall area. Resistance of the wall area without glass is 11.54.

Interestingly enough, the air conditioning load of a similar building designed prior to the energy crunch would have been one ton for every 300 square feet of floor area. The Citizens Mutual building has a requirement of one ton air conditioning load for every 666 square feet of conditioned space, or one ton for every 888 square feet of gross area. In other words, Citizens' has a heating load equal to 70% the state maximum and a cooling load requirement less than 50% of the previously accepted values.

In an effort to establish the solar design approval, a review was made of the heating degree days and the expected full load cooling hours for the Leavenworth Building. In TABLE 1, degree days and annual full load cooling hours are tabulated for various locations.

TABLE 1

	Heating Degree Days	Cooling Full Load Hours
Leavenworth, Ks.	5200	1000
Dallas, Tx.	2400	1200
New Orleans, La.	1400	1400
Tampa, Fl.	700	1500

It became apparent after reviewing the data in TABLE 1 that the design approach had to consider heating as the most important aspect of the solar design. The annual cooling requirement of Leavenworth is 67% of Tampa, yet the heating is almost six (6) times greater.

With the design approach established, nine computer runs were made to determine the ideal choice of collector type and array size. The computer runs included tracking concentrating and flat plate type of various sizes. Life Cycle Costing was completed on each of various combinations. Table 2 lists three of the computer runs, all of flat plate collector type, giving the pertinent data.

TABLE II

	Alt. #1	Alt. #2	Alt. #3
Collector Area	2220	1665	1332
Number of Panels	120	90	72
Cost/Sq. Ft. of Panel	$54.30	$66.16	$75.41
Heating % of Annual Load	91%	69%	55%
Cooling % of Annual Load	70%	56%	48%
Cost/Earning Ratio	100	125	162

Alternate No. 1 was chosen for implementation due to the lowest cost/earning ratio. The other computer runs were for tracking collectors, heating only and cooling only. None were as cost effective as the chosen Alternate No. 1. Since heating was the major concern, the largest volume of solar heated water was the goal. Studies indicated that 100° water would meet the peak heating requirement, whereas cooling required 190°. This data led to the selection of the flat plate collector and its ability to collect more diffuse radiation over the tracking collector.

The building orientation and arrangement indicated a need for five zones of temperature control. System design was five water to air heat pumps with an outdoor cooling tower, and five solar heated absorption units for cooling. Following is a tabulation of space temperatures and the corresponding system mode of operation:

Space Temp.	Mode of Operation
78°	Auxiliary Heat Pump Cooling
76°	Solar Absorption Cooling
74°	Economizer Cooling
72°	Solar Direct Heating
70°	Solar Assisted Heat Pump
68°	Auxiliary With Heat Pump

Solar absorption cooling will handle the entire cooling load as long as sufficent quantities of 190° water are available. A chilled water pump and piping system transfer the absorption cooling to the air stream with a coil in each zone duct. The absorption units are all in parallel on the chilled water loop and are staged on as required to maintain the chilled water supply temperature at 45° F. Variable flow through the collector was provided to assist in delivering the highest water temperature possible. The solar water storage tank capacity of 6,000 gallons was divided into two (2) three thousand gallon tanks, one for summer (higher temperature) use and both for winter (highest volume) use.

Solar direct heating, accomplished with a coil in the air stream of each zone, will provide total heating as long as the solar heated water is 90° or higher. If solar heated water is below 90° and above 68°, the solar assisted heat pump will provide the necessary heating at a coefficient of performance of approximately 2.85. Between the need for direct solar heating and absorption cooling, the outdoor and return air dampers will modulate to provide cooling by natural means from cool outdoor air.

The system, then, included a water to air heat pump for each of five (5) zones in series with a chilled water coil and hot water (solar water) heating coil. The additional fan resistance necessitated the addition of a booster fan in series with all five (5) zone heat pumps and connected to the common return air and outdoor air duct. Air filtration was accomplished at the booster fan and deleted from the individual zone heat pump.

The main banking area has a vaulted ceiling, following the pitch of roof and offering an ideal opportunity to pick up the stratified hotter air at the roof peak in the winter. High return air was provided for winter operation and a low return for summer. Supply air to the individual spaces was through floor grilles, thus permitting the circulation of lower temperature air for heating, a situation well suited for direct solar heating.

The solar system, as stated earlier, will provide 91% of the heating and 70% of the cooling, and is completely automatic. The Owner had instructed the designers to "keep the system simple"; that their business was "savings and loan and not mechanical system operation". With these instructions in mind, the designers set out to provide the automatic system. Approximately 20% of the system cost was for temperature control, or almost $11.00 per square foot of collector panel. The control system is pneumatic, because of cost advantages, and includes step controllers for sequential control of absorption units.

Six months of operating experience has been gained with the completed system. Only minor problems have been encountered to date. Power failure, with the sun shining, was the first problem. A rapid increase in collector temperature and pressure occurred and the safety relief valve functioned as intended, with the resulting loss of antifreeze solution. The relief valve didn't operate until the collector circulation pump was restarted on power restoration. A check of the system piping found that the Contractor had installed the relief valve at the pump discharge rather than at the expansion tank connection (point of no pressure change) as called for on the design drawings. A relocation of the relief valve has eliminated this problem.

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CITY OF HUNTSVILLE
SENIOR CITIZEN'S CENTER
SOLAR HEATING AND HOT WATER SYSTEM

W.R. Dickson

INTRODUCTION

This project is an important architectural project in the sense that esthetic considerations were equally as important as solar technology. The site is the visual centerpoint of Huntsville's major park area. The project is completely surrounded by fine public buildings.

Hopefully, the project demonstrates that solar systems can be interesting integral elements of good architectural solutions. The collector system arrays are used as primary architectural treatments and provide the dominating element of the entire design.

EXISTING BUILDING ORIENTATION

This project is retrofitted to an existing building. The nearest toward south facade actually faces 34° east of south. Absorber surfaces, therefore, required a tilt back toward south.

INTEGRATED PREFABRICATED SOLAR ARCHITECTURAL PANELS

There are twenty-six fully assembled solar architectural panel units. Each unit was crane-lifted to pre-installed steel angle mounts. Panels are twenty-six feet long and six and one-half feet wide. These are thin-shell precast fiberglass reinforced concrete and are self-spanning between two steel mounting angles. Each preassembled panel included insulation sealed in cover glass and absorber plate with stub-outs to the collector fluid manifold. Exposed faces of panels are in two planes each at thirty degrees to the panel back. These planes form a center ridge. The absorber assembly is recessed into the westward of the two face planes. This tilts the absorbers toward the south to correct for the building orientation.

ARCHITECTURAL AND CONSERVATION ADAPTATIONS

The solar architectural panel arrays are flanked by new end wall adaptations. These are designed to harmonize with mass, line and angles of the solar arrays. These walls are provided with additional insulation as a conservation measure.

Existing full glass walls on the north and east were redesigned. Each alternate window panel was covered with a new insulated facing panel. Remaining single pane glass was replaced with double glazing.

ABSORBER PLATES

Absorber plates are aluminum fin tube construction with single row copper tubing. The fin tube configuration entraps diffused radiation from a wide range of directions. Consequently, test results indicate a relatively higher radiation absorption under light overcast conditions. Diffusing cover glass aid this effect.

HEAT TRANSFER SYSTEM

The solar heat transfer system is designed with a "fail safe" philosophy. The collector loops are totally sealed. They contain two hundred thirty gallons of Dow Corning Syltherm 444. This is a relatively inert fluid which boils at 600°F and freezes at minus 120°F (-120°F). These loops contain compressed air expansion tanks and are never drained down. All pipe in this system is copper and all joints are high melt type solder. No rubber or synthetic gaskets are used and expansion loops are used instead of expansion joints. Pumps are in-line canned types or standard types with high performance seals.

Building heat is stored in a 3,000 gallon atmospheric vented insulated water tank. Heat is transferred to this water from collector loop fluid by single wall tube-in-shell exchangers. Heat for domestic hot water to preheat storage is transferred from one of the two collector fluid loops with a double walled exchanger which is vented between walls. This exchanger is welded copper construction of a proprietary design by Solar Unlimited, Inc. It has excellent transfer characteristics from collector fluid to water.

Stored solar heat is distributed throughout the building with conventional pre-existing hot water heat distribution equipment.

Back-up heating is by pre-existing gas-fired boiler.

ADMINISTRATIVE, DESIGN TEAM, SOLAR HARDWARE SUPPLY, CONSTRUCTION & COSTS

Administrator for the City of Huntsville was Glenn Wallace, Landscape Architect and Director of the City Parks and Recreation Department.

Project Architect and Overall Coordinator was W.R. Dickson, Architect of Dickson and Associates, Huntsville, Alabama.

Solar System Designer was Bruce Novell, Design Engineer of Solar Unlimited, Inc., Huntsville, Alabama, with other engineering support from his company.

The solar hardware supplier was Solar Unlimited, Inc. of Huntsville, Alabama. By separate negotiated contract with the City, this company supplied all of the specialized solar system components and solar engineering design technology. By agreement, they functioned as associated professional support to the architect.

The architect designed the building adaptations and coordinated all work into complete drawings and specifications and provided conventional contract bidding procedures and construction supervision.

The construction contract was awarded to Parker Construction Co. of Huntsville, Alabama, and provided for all adaptations to the building to receive solar hardware, conservation modifications, architectural treatments and complete assembly and installation of all items furnished by the City under separate contract with the solar hardware supplier.

By separate negotiated agreement, Solar Unlimited, Inc. will furnish operating maintenance and system monitoring.

Solar hardware supply & design contract. . .	$ 79,834.00
Construction contract.	95,700.00
Architectural fees	12,000.00
Estimated contingencies.	1,000.00
Total project cost.	$188,534.00

BUDGET & COST CONTROL

The approved complete cost budget for this project was $180,000.00.

The completed cost was $188,534.00.

Three factors contributed to this relatively successful cost control result.

1) During the early design concept stage, the design team did extensive cost studies. This work compiled cost data for all anticipated cost items and developed the recommended budget which was approved.
2) Cost studies were strictly applied as design guidelines.
3) A special public relations program was instituted to interest building trade contractors for the project. General and special invitations were issued to contractors and sub-contractors to attend a pre-bid briefing. About 150 people attended this briefing. Complete plans and specifications were shown and discussed and an illustrative construction model and all proposed solar equipment was illustrated and explained.

OPERATIONS

Currently, no major problems with the solar system have occurred. The system functions as intended and shows promise of meeting performance objectives. It has not been in operation long enough to be fully evaluated.

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Days Inns

Solar and Energy Conservation Systems

James A. Grissett, Jr.

The purpose of this paper is to give a brief history of Days Inns experience in Solar and Energy Conservation Systems and our plans for the future.

In April of 1970 Days Inns opened their first 60 unit motel at Savannah Beach, Georgia. By the end of 1973 there were about 200 locations; when the Oil Embargo of 1974 was imposed. Today there are over 301 locations and over 42,000 rooms in the chain.

Days Inns formed their Energy Conservation Group at the beginning of the 1974 oil crisis and has used this group to review, study and implement the various Energy Conservation Programs for the Day Companies. We literally looked at hundreds (100's) of methods to conserve energy and have rejected about as many as we have looked at and tested on our units in the field.

The energy conservation program was initially set up to be initiated in three (3) phases with the following general categories:

Phase I: Those items which could be put into effect immediately such as manually resetting thermostats, turning off equipment when not in use, improved maintenance, etc.

This involved more attention from our local managers and personnel but did not involve additional cost. It was our experience that this phase could reduce the respective utilities by 15%-25% depending on the particular conditions existing at the site.

Phase II: Those items which required the addition of devices or controls to restrict usage, load management, reviewing utility rates and metering arrangements.

This involved investigation of the systems, testing, and cost effectiveness of the various devices. We set up our range of optimum payback of 6 months and not to exceed 18 months.

The results of this phase include a water conservation package where we installed devices on 10,000 rooms during the summer of 1978 which gave us an average payback per room of about 2 months.

We currently have under test about 1500 key operated devices with high low limit override installed on room A/C units. We have monitored these for about 12 months and comparisons with previous year indicate up to 25% reduction in Electrical Consumption.

Phase III: Those items or areas which require the addition to or modification of existing systems including Solar Energy, alternate energy sources, heat recovery, etc.

We did not specifically set a fixed limit on payback on these type systems, but in general, felt those areas impacted by energy sources subject to 10% or more annual esculation rates with a projected payback of not more than 8 years were our prime target areas.

The remainder of this paper gives a brief outline of our experience with Phase III Solary Energy Systems.

Days Inns first Solar System was installed at our Anderson, S. C. unit (I-85 and S. C. 187), which was put into operation in November, 1977. This was an "open" drain down type, with 750 $ft.^2$ of collector, 1000 gallon storage designed to heat 40% of the 1800 gallons of hot water needed per day for the 116 room Days Inn and Lodge complex. The cost of the project was $20,325.00 of which the U. S. Department of Energy funded $10,163.00. The anticipated payback by using solar energy to pre-heat the hot water is seven (7) years based on the total project cost. This project has been written up in previous D.O.E. project summaries for readers interested in the details. Also refer to Figure I and II attached for actual operating history.

Current Solar Projects Under Construction and Future Proposed Projects:

Based on our experience with the Anderson. S. C. Days Inn, we currently have three (3) additional systems under construction and eight (8) additional systems planned.

The Department of Energy's grant of $167,037.00 will be matched by an equal amount from Days Inns, disbursed over a one year period.

These funds will implement installation of projects using solar energy to heat hot water in 11 Days Inn properties in the South and Southwest.

Each solar hot water system will cost an estimated $30,000.00. Installations are scheduled on a four stage cycle which began March, 1979, with a completion date of mid-March, 1980.

The following agenda details the Days Inns to receive the solar installations and the specifics:

<u>Stage I 3-15-79 6-15-79</u>	Contracts were awarded on March 15, 1979, for completion by June 15, 1979 for the following:
Unit 1	I-85 & Shallowford Road Atlanta, Georgia, with Welchel Solar Enterprises, Inc.
Unit 2	I-95 & Cagle Road Jacksonville, Florida, with Independent Living, Inc.
Unit 3	Abercorn & Mall Boulevard Savannah, Georgia, with Solar Designs of Taylors, South Carolina, and M. O. Seckinger Co.
<u>Stage II 6-15-79 9-15-79</u>	
Unit 4	I-4 & Florida 436 Altamonte Springs, Florida
Unit 5	I-45 @ NASA/Webster Houston, Texas Contractor to be determined at later date
Unit 6	I-635 & 2753 Forest Lane Dallas, Texas Contractor to be determined at later date.

Stage III 9-15-79 12-15-79

Unit 7	I-30 & 6222 Beltline Road Dallas, Texas (Garland) Contractor to be determined at later date
Unit 8	I-45 @ S. Wayside or I-45 & Cavalcade, Houston, Texas Contractor to be determined at later date
Unit 9	U. S. 27 & Florida 19 Clermont, Florida Contractor to be determined at later date.

Stage IV 12-15-79 3-15-80

Unit 10	Proposed Days Inn in Raleigh, North Carolina
Unit 11	Proposed Days Inn in Columbia, South Carolina

Typical Hot Water Preheat System:

The solar hot water plant is in effect, a hot water preheat system. The solar system is composed of flat plate collectors arranged in parallel rows facing South. The collectors, are placed on the roof of the Days Inn, with a total collector area of not less than 1,000 square feet, and a storage tank of not less than 1,000 gallons.

Each solar system is designed to heat approximately 65% of the hot water needed per day for the Days Inn or Days Lodge complex. The anticipated payback by using solar energy to heat hot water is projected not to exceed seven years based on the total project cost.

Stage I - Unit 1 (Atlanta, Georgia) above should be in operation by the end of July, 1979; Unit II (Jacksonville, Florida) went into operation on June 19, 1979 and Unit III (Savannah, Georgia) went into operation on June 22, 1979. Refer to Figure II for Solar Summary comparing existing Anderson, S. C. unit with the three (3) units under Stage I construction.

Conclusions:

1. Compare economics of available energy sources and utilities for each project.

2. Arrange with utilities for most economical rate and metering arrangement.

3. Solar Energy has proven most cost effective for Days Inns to preheat domestic hot water where existing energy source is electric exceeding 3¢/KWH.

4. Keep systems simple as possible including close-coupled piping systems, standardized design, packaged components where available, utilize factory mounting assembles where possible and shop fabrication of sub-assembly units.

FIGURE I

ANALYSIS OF SOLAR HEATING SYSTEM
Days Inn - Anderson, S. C.

Summary of Data

	Nov. '76 to Oct. '77	Nov. '77 to Oct. '78	Net Difference	Percent Difference
Total KWH	1,102,800	1,124,400	+21,600	2%
Total Electric Bill	$28,971.60	$31,308.24	+$2,336.64	8%
Total Rooms Rented	27,984	30,912	+2,928	10%
KWH/Rented Room	39.4	36.4	-3.0	7.6%
Electric Cost/Rented Room	$1.04	$1.01	$0.03	3%

Conclusions

1) The fact that the usage of electricity rose 2% and price paid for electrical service rose 8% indicates that the cost of electricity increased roughly 6% between the two periods.

2) The fact that the amount of energy used increased by only 2% and that the number of rooms rented increased by 10% indicates that 7.6% less electricity was used per rented room after the solar system was installed. This corresponds to a 3 KWH savings per rented room.

Calculation of Savings

Yearly savings = (total rooms rented) X (KWH saved/rented room) X ($.03/KWH)

Yearly savings = (30,912 rooms) X (3.0 KWH/room) X ($.03/KWH)

Yearly savings = $2,782.08

Payback period on DIA investment.

$$\text{Payback period} = \frac{\$10{,}000}{\$\ 2{,}782} = 3.6 \text{ years}$$

FIGURE II

SOLAR SUMMARY

	Anderson S.C. (67)	Shallowford Lodge (88)	Savannah Mall (94)	Jacksonville Cagle Rd. (41)
Electric Rate	$0.035/KWH	$0.038/KWH	$0.042/KWH	$0.049/KWH
Avg. Temp. °F	62	61	67	69
FY78 Electrical Consumption ($) Motel Only	$30,948	$40,814	$42,451	$115,200
Min. Design Load (% of Hot Water)	40%	65%	50%	65%
Est. Gross Annual Savings (Annual $ x 15% est. Hot Water x Design Load) ($)	$ 1,857	$ 3,979	$ 3,184	$ 11,232
% of Site Load	100%	100% (50% if only 1 bldg.)	100%	45% (120% of 266 Units)
Est. Net Annual Savings ($)	$ 1,857 ($ 2,782.08 Act.)	$ 3,979 ($ 1,989)	$ 3,184	$ 5,054
System Cost to DIA (1/2 Actual) ($)	$10,000	$18,042	$15,000 est.	$ 15,823
Payback (yrs)	5.4 Years (3.6 Act.)	4.5 Years (9 Years)	4.7 Years	3.1 Years

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Solar System Corporate Headquarters Office Building

Georgia Power Company
Walter R. Hensley
Dwight Jones

The GPC building (See Figure 1) is composed of two elements, a 472,000 ft^2 24-story office tower with an adjacent 294,000 ft^2 solar collector crowned 3-story low-rise. The office tower will house homogenous office space. The low-rise will house multiple special use functions, such as training facilities, data processing facilities, TV studios, kitchen, print-shop, carpenter shop, vehicle maintenance facility and GPC's computerized load management center which controls the utility's entire power supply network.

The building has been designed to minimize energy consumption. Its orientation, proportion, and shape were selected for their energy conservation characteristics. The building's outer skin material, which is all glass, was selected because the reflectivity of the glass rejects larger amounts of solar radiation than other skin materials such as concrete, stone, aluminum, or various other metal panels. Its light weight obviates the need for structural support and foundation, and it is economical in terms of initial cost and maintenance. To further inhibit solar heat gain, transparent vision glass has been reduced to a physiological and psychological minimum. On the east and west facades, windows have been eliminated altogether. Service cores that include unoccupied spaces, such as elevators, stair towers, mechanical rooms, storage room, etc., were located adjacent to the east and west walls to serve as additional thermal barriers. The south and north walls will be built of 50% vision glass. The vision glass in the south wall will be shaded in the summer months by setbacks and sunshade tubes. The north wall will be sheer and unshaded. All vision glass will be bronze double glazed (reflective) panels. Nontransparent walls will be insulated spandrel glass with bronze reflective coating to match the vision glass.

A task-oriented lighting scheme using ceiling mounted 2' x 2' deep cell parabolic fluorescent fixtures was devised to provide 60-70 ESI (Equivalent Spherical Illumination) footcandles to task locations. The lighting scheme will consume only 1.65 watts/ft^2 which is 2 to 4 watts/ft^2 less than the average Atlanta office building. An open and semi-open office plan maximizes light distribution from the fixtures and takes advantage of natural light from the vision glass.

The office tower H.V.A.C. system utilizes the latest state of the art variable air volume air delivery system with one supply air handling unit per floor. Interior control zones are supplied through a variable air volume induction box that induces ceiling plenum air to mix with primary air to maintain minimum air changes to occupied space. Exterior control zones are supplied through a powered induction box with variable volume primary air damper, constant volume fan and electric duct heater. Electric duct heater is locked out until primary air damper is closed and is also interlocked with the lighting system to limit duct heaters to 60% when lights are operating. Each air handling unit has full sized outside air and relief air dampers to provide enthalpy controlled air side economizer. Relief air is ducted down to provide ventilation air for mechanical equipment room, telephone equipment room and for make-up air to kitchen range hoods.

The low-rise H.V.A.C. system consists of special types of air delivery systems that provide space thermal conditioning for many separate and varied occupancies. Variable air volume delivery systems are generally provided in all areas. However, in some areas where constant volume is required, a bypass multizone system is employed. All air handling systems in the low-rise will also be equipped with air side economizers.

The building hydronic systems are comprised of five subsystems:

1) Chilled water
2) Heating hot water
3) Condenser water
4) Solar energy collection, and
5) Solar energy utilization.

A conventional closed loop chilled water system utilizing two 650-ton centrifugal chillers will supply chilled water for building cooling. The second chiller is equipped with a double bundle condenser to use the heat of rejection for building heating. In addition to the electric driven centrifugal chillers, a 260-ton solar heated hot water driven absorption refrigeration machine will provide chilled water for building cooling. The absorption machine can operate in series or parallel with either of the electrical driven centrifugal refrigeration machines. A 300,000 gallon baffled underground chilled water storage tank is included to be used during the day to reduce the building peak electrical demand. It can be charged from either of the electric driven refrigeration machines at night during off-peak hours or from the solar driven absorption refrigeration machine on weekends and holidays or during winter months when chilled water demand is minimal because of enthalpy controlled air side economizers on all air handling systems. The 300,000 gallon chilled water storage tank has been calculated to be approximately 80% efficient and can supply chilled water to carry the entire building for three hours.

Heating hot water is supplied to the low-rise structure and the first three floors of the office tower. Heat of rejection from the double condenser bundle chiller will be used to heat the low-rise or will be stored in the two 25,000 gallon tanks. The 50,000 gallons of hot water produced during the day from either heat of rejection or solar energy can be used to heat the low-rise at night. Even though computer simulations have never indicated a need for a conventional source of heat, a 720 kw electric boiler will provide necessary back-up and standby capacity.

Condenser water system provides condenser water to each refrigeration machine. The cooling tower is located on trade adjacent to the south wall of the low-rise.

The Solar Energy Collection System (SECS), consisting of 23,760 ft^2 of parabolic trough concentrating collectors located on the low-rise roof, collects and transfers solar energy by means of solar heated fluid to a heat exchanger. This energy will be used for building heating and cooling as well as for domestic water heating. The SECS will be capable of displacing 10-15% of the required purchased energy for the entire building and can provide one-third of the peak cooling load for the building. A unique feature of the SECS is the fact that it has been selected through a competitive bid process in which 14 solar collector manufacturers were invited to submit fixed price guaranteed performance proposals. The bid package stressed reliability and cost effectiveness. This achievement makes a significant step in helping to move the emerging solar collection industry out of the realm of government funded research and development and into the commercial market place. The successful solar contractor was Jacobs - Del Solar Systems Inc., Pasadena, California.

The Solar Energy Utilization System (SEUS) is designed to interface the SECS with the building heating, cooling, and domestic hot water systems. SEUS circulates solar heated hot water from the heat exchanger in the SECS through the 260-ton absorption refrigeration machine to provide chilled water for cooling; through a heat exchanger in a 2,500 gallon domestic hot water tank or through heat exchangers in each of the 25,000 gallon building heating hot water storage tanks.

A sophisticated computerized central control and monitoring system (CCMS) controls all building life safety functions, security functions, and environmental control systems. This computer-based digital control system selects the most energy efficient method of maintaining environmental conditions. The energy supplied by the solar energy collection is the first priority of the control system. Number two priority is dependent on the building load, time of day, time of year, and projected building load.

Final preconstruction energy usage analysis (See Figure 2) indicate that building energy consumption without credit for solar will be 53,880 BTU/S.F./Yr, a 43 percent reduction from the 94,353 BTU/S.F./Yr of a comparable typical office building in Atlanta, Georgia. Use of the solar system will drop annual consumption to 46,276 BTU/S.F./Yr (See Figure 2).

This building, despite its innovations, will cost only $42.00 per square foot, which is comparable to any typical corporate headquarters office building. The solar energy collection system, which cost $1,050,000, is not included in this price.

The solar array of 1481 Del concentrating parabolic trough collectors with fixed receiver tubes (See Figure 3) are arranged in eleven sub-arrays (See Figure 4) with the collectors spaced at 4' - 7" centers in a north-south orientation.

Each parabolic concentrator is composed of glass mirror segments. Each segment is 24" long, sagged to the appropriate parabolic shape and back silvered. The silvering is protected from the weather by the glass on the reflecting side and an inert, non-porous coating on the other side. The mirrors concentrate the sun's rays onto the stationary receiver tube positioned at the focal point and center of rotation of the parabola. The focal point is on the center of gravity of the concentrator.

Each collector has been designed to minimize field maintenance and repair. The second surface mirrors will not degrade, and accidental breakage is mollified by the mirror segment approach. If necessary, replacement of individual mirror segments in the field is easily accomplished in a few minutes by one person.

Criteria for Selection of Trough Size

A. Small mirrors can be more easily shaped to the final parabolic contour and do not require a supporting substructure like honeycomb or plywood which can change dimension and optical figure with long exposure to the weather.

B. Best compromise relative to the effect of wind loads on the cost of collector structure and foundation requirements.

C. Easy to mass produce - can be handled by one person on the production line.

D. Mirror tooling costs are less for small mirrors.

E. Small mirrors are easily packaged and shipped.

F. Ease of field maintenance.

Criteria for Selection of Back-Silvered Glass Reflector

A. Glass can be sagged to the final parabolic shape without the need for a supporting substructure.

B. Glass is inert and durable; mirrors of this type have been exposed to the elements for over 25 years without loss of reflectivity in the pilot model of the solar furnace at Odeillo - Font Romeu, France.

C. Silver has the best reflectivity (97.7%) of any material known for one air mass solar spectrum (ref. Haas, Solar Energy, Vol. 9, No. 1, 1965).

D. Second surface glass mirror provides required weather protection for the silver (absorbtivity of low iron glass is 6%).

E. Glass is a low cost material and in high volume worldwide production.

Stationary Receiver Tube

The fixed, hard-mounted steel receiver tube is ½" O.D. and is plated with a selective coating of black chrome over dull nickel (Spec. N7512329) (NASA TM-X-3126) on its outer surface. This coating has an absorbtivity of 0.95 and an emissivity of 0.15 (0.25 at 600° F). The energy transport fluid makes a single pass through each receiver. Since the steel receiver tubes are in a completely fixed position and do not move, fluid leaks will be eliminated.

The heat absorption efficiency of this kind of system is strongly dependent on the size of the receiver tube. For a given flow rate, smaller receiver tubes have higher liquid film coefficients and transfer the solar energy to the transport fluid within the tube more effectively. In addition, heat losses from the receiver tube decrease as the tube diameter decreases.

Each receiver tube is surrounded by a non-evacuated 38 mm. O.D. pyrex glass tube to reduce convection losses and protect the selective surface from the weather. The receiver tubes are connected using standard fittings. These inter-connections are insulated with stock-size, commercially available material.

Criteria for Selection of Tube Size (½" O.D.)

A. Best compromise between thermodynamic performance and power required for pumping.

B. For a given liquid flow rate, small receiver tubes transfer the solar energy incident on the tube to the liquid within more effectively due to higher velocities and film coefficients. Heat loss from the receiver tube decreases as the tube diameter decreases.

C. Easy to make leak-tight pipe connections using small hand tools.

Criteria for Selection of Tube Material (1015 steel)

A. Hard-mounted, non-moving receiver tube system (receiver tubes and connections between receiver tubes) eliminates the need for moving seals, which are always a potential lead problem. Steel will easily meet code requirements for pressurized operations.

Criteria for Selection of Pyrex Glass Insulating Tube (38 mm O.D.)

A. Pyrex will withstand thermal shock.

B. Standard, commercial size (38 mm O.D. 2 mm wall) closest to optimum annular gap prescribed for ½" O.D. receiver tube.

General Specifications

Concentrator

Projected area	24 in. x 96 in.
Pointing or aiming slope error	$\pm 1.0^{o}$ or less
Figure slope error	0.5^{o} or less

Mirror reflectivity	0.90 minimum
Mirror thickness	0.120 in.
Receiver - Insulating Pyrex Glass Tube	
Outside diameter	38 mm
Wall thickness	2 mm
Emissivity	0.90
Transmissivity of solar flux	0.90
Receiver - Steel tube	
Outside diameter	0.50 in.
Wall thickness	0.028 in.
Length	96 in.
Absorbtivity (average)	0.95
Emissivity at 600° F	0.25
Emissivity at 212° F	0.11

Tracking System Description

A Delavan photo sensor unit looks at the sun and controls the power to the reversible motor which drives a shaft. The shaft transmits positive rotary motion through a worm gear at each concentrator. A number of concentrators can be rotated by each drive motor. The drive system is sealed for protection from dust and water and is compact and low in cost. The control system logic will place the reflecting surfaces face down at night and at other times if desired. This automatic system also includes a manual switch for service convenience. For inital on-site focusing, the tracking drive mechanism includes a means for individual adjustment of each concentrator.

The system has been designed so that the stationary receiver is on center of gravity of the rotating system. This minimizes the size of the motor and reduces the cost and wear associated with unnecessary weight.

Criteria for Selection of Tracking System Arrangement

A. Low cost and high reliability.

B. Precise alignment is easily maintained by the Delavan sensor and solid state control system.

C. Mechanical advantage of worm-drive system is inherently self-locking relative to wind load turning moments.

D. Parts are stock items.

Field Installation

To facilitate field installation, the collector has been sized for handling by two people. The time and skill required to install each collector is modest. Each collector is bolted to the support structure through four over-size holes. Two plumbing connections-fluid in and fluid-out are required with the connectors already attached to the collector. The tracking drive shaft must be connected to the adjacent collector's drive shaft. A 24 volt. d.c. connection is required for the motor and a sensor serving a number of collectors.

The frame is made from square steel tubing which is readily available and easy to weld and align during construction.

SECS SCHEDULE

Award of Contract or Notice to Proceed	15 March 1978
Initiation of SECS Design	1 April 1978
Sandia Laboratory Collector Test Reports	30 April 1978
DOE Design Review	1 June 1978
Initiate Quarterly Reports to DOE	15 June 1978
Desert Sunshine Collector Test Reports	30 June 1978
SEUS Out for Bid	1 July 1978
SEUS Bids Received	1 September 1978
Award of Contract/Building Groundbreaking	1 October 1978
Submission of Final SECS Shop Drawings	1 January 1980
Access to Roof for Installation	1 July 1980
Substantial Completion (Beneficial Occupancy)	1 December 1980
Final Completion	1 January 1981
End One Year Jacobs-Del Warranty Against System Failure	1 Janaury 1982
End Five Year Jacobs-Del Warranties Against Defect and Corrosion	1 January 1986

PROJECT SUMMARY

(Georgia Power Co.)

Building Type

Office/Operational Facilities

General

Site: 17 acres, urban
Area: 766,000 gsf
Floors: Tower, 24
Base, 3
Construction:
Tower - steel frame with glass curtainwall
Base - prestressed concrete with brick exterior
Total Project Cost (incl. land): $62.5 million
Completion: December 1980

Design Data

Occupancy: 2,400
Operation: Tower - 40 hrs./wk.
Base - 168 hrs./wk.
Heating Degree Days: 3,095 - 65°F
Cooling Degree Days: 1,589 - 78°F
Winter Temps: Indoor, 72°F (55°F setback)
Outdoor, 23°F
Summer Temps: Indoor, 78°F
Ourdoor, 92°F

Energy Use (predicted)

Summer Peak Demand: 14.8 Btu/ft^2
Winter Peak Demand: 15.2 Btu/ft^2
Consumption: 53,880 Btu/ft^2/yr

Selected Features

- End core thermal buffer
- South window setback & sun-screens
- 80% exterior insulated spandrel glass (U=0.05)
- 20% reflective insulated vision glass (U=.53, SC=0.23)
- Adjacency of interrelated functions
- Clustering of 24 hr/day functions
- Earth berming - base building
- Enthalpy economizer
- Lighting system - 1.65 Watts/ft^2
- Variable air volume terminal units - interior zones
- Powered induction box with electrical heat - exterior zones (no reheat)
- Central computer building control
- 23,760 ft^2 of lineal parabolic trough tracking collectors
- 50,000 gallon hot water storage tank
- Solar space heating
- Solar absorption space cooling
- Double bundle chiller
- 300,000 gallon chilled water storage tank

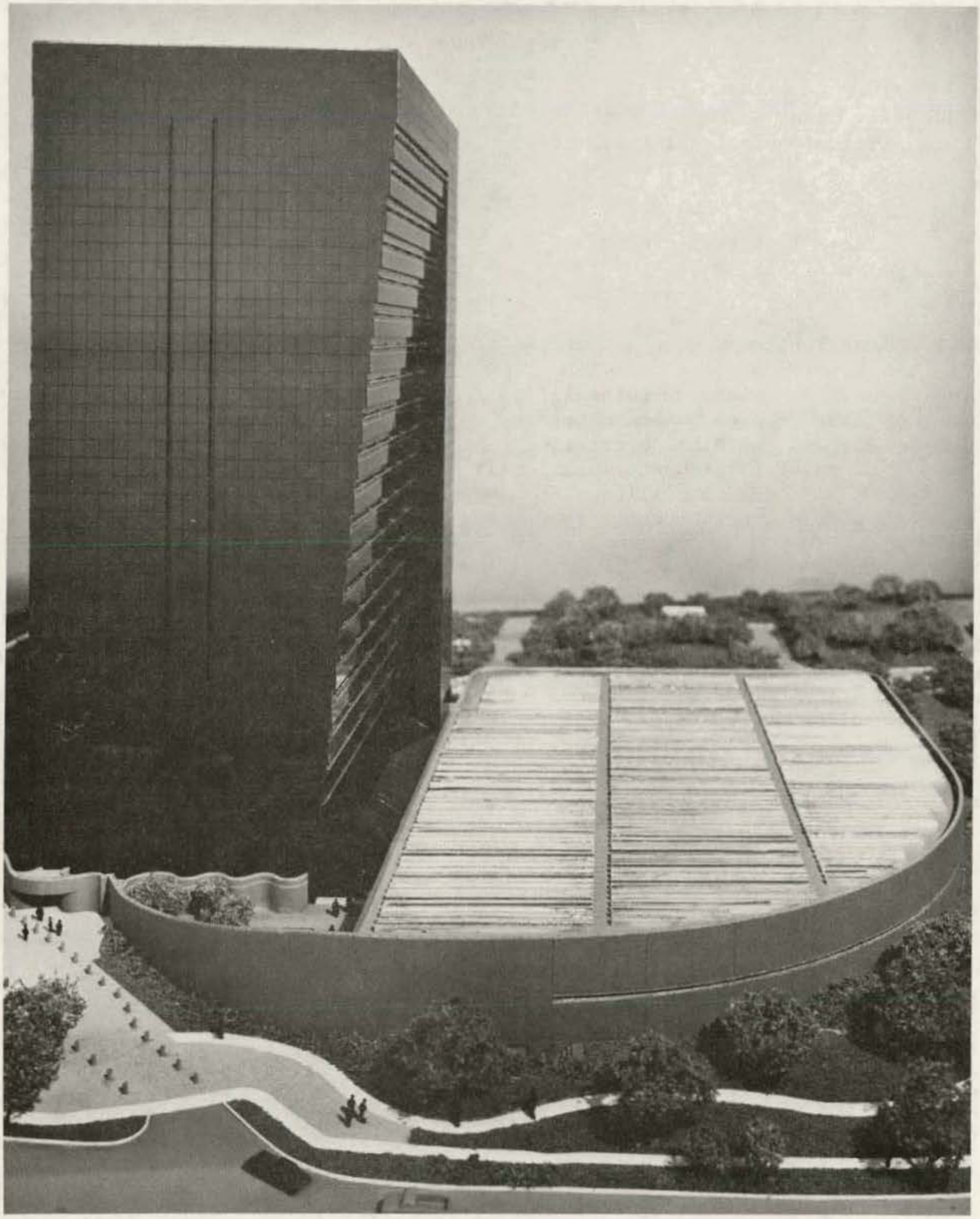

Fig. 1 – View of Building From the Southwest

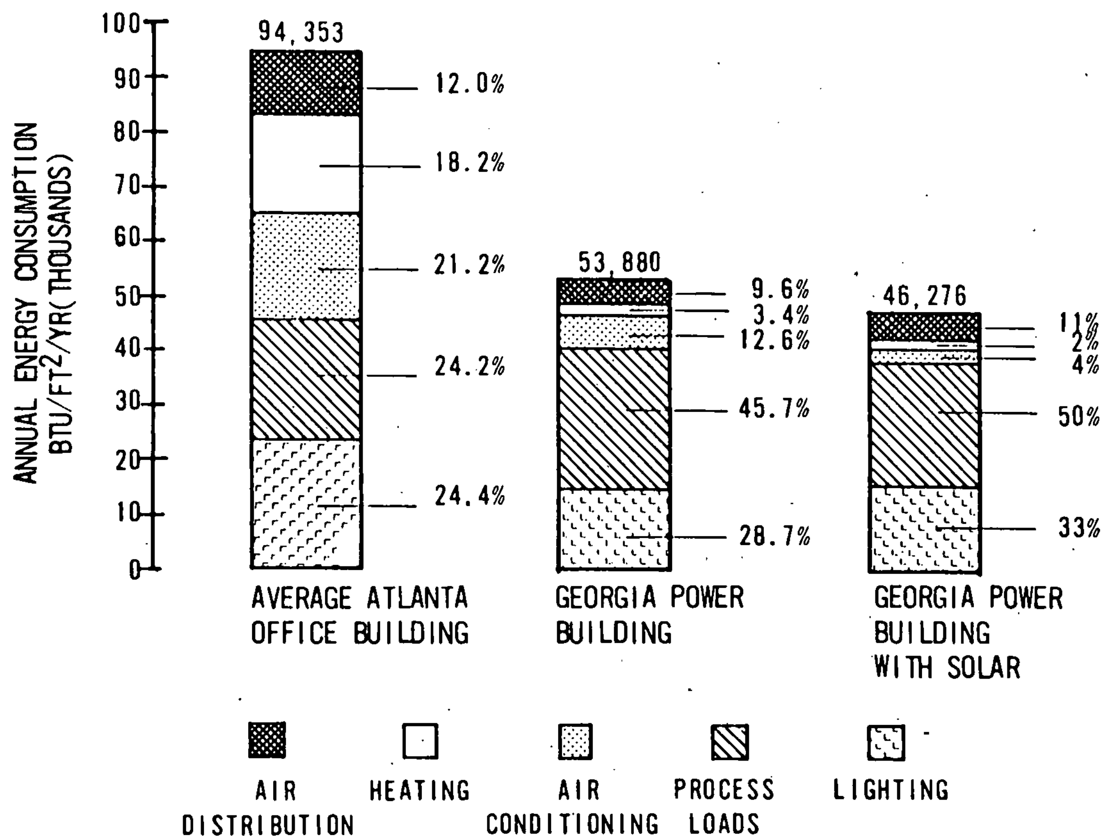

Fig. 2 — Energy Consumption Comparison

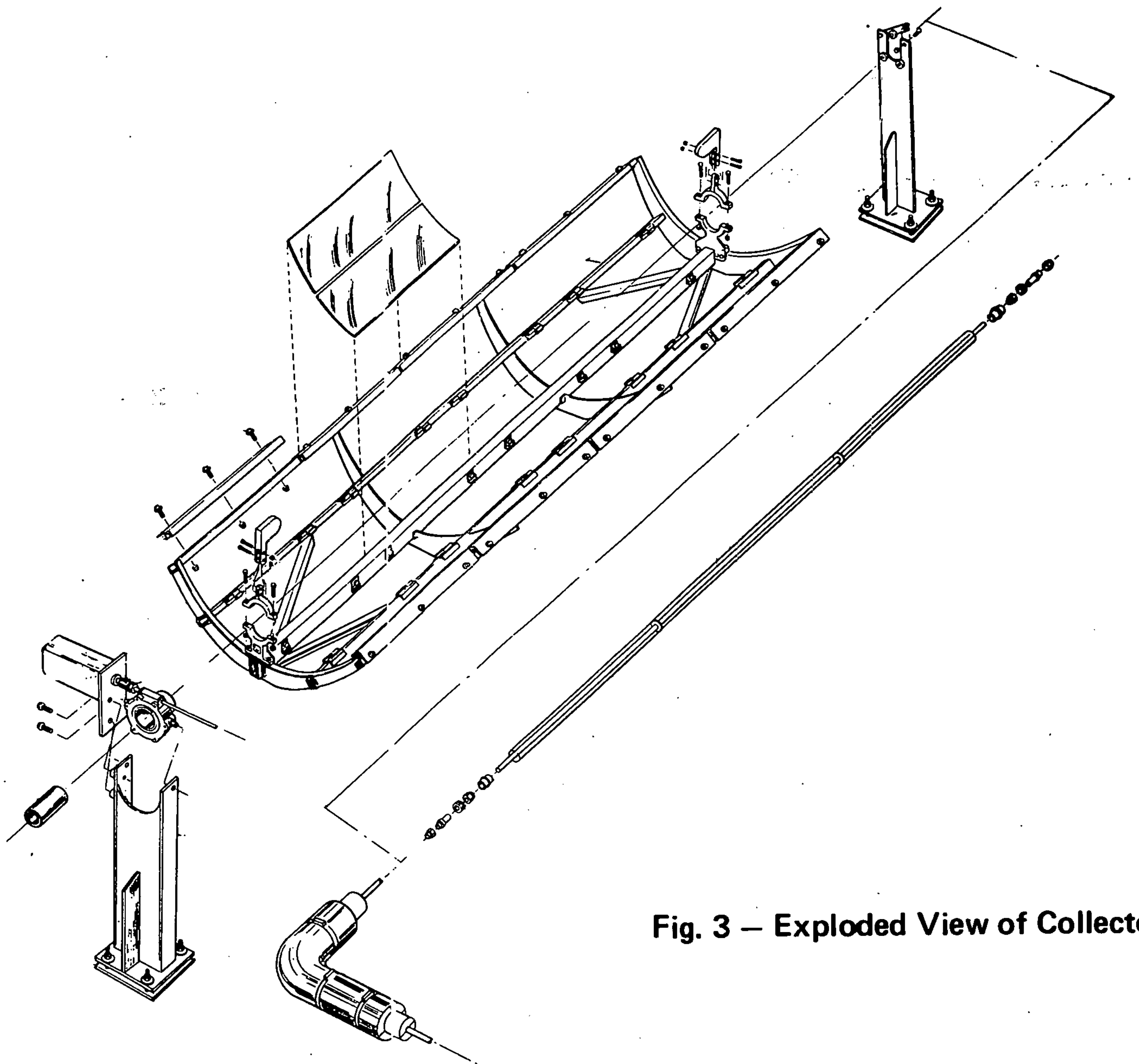

Fig. 3 – Exploded View of Collector

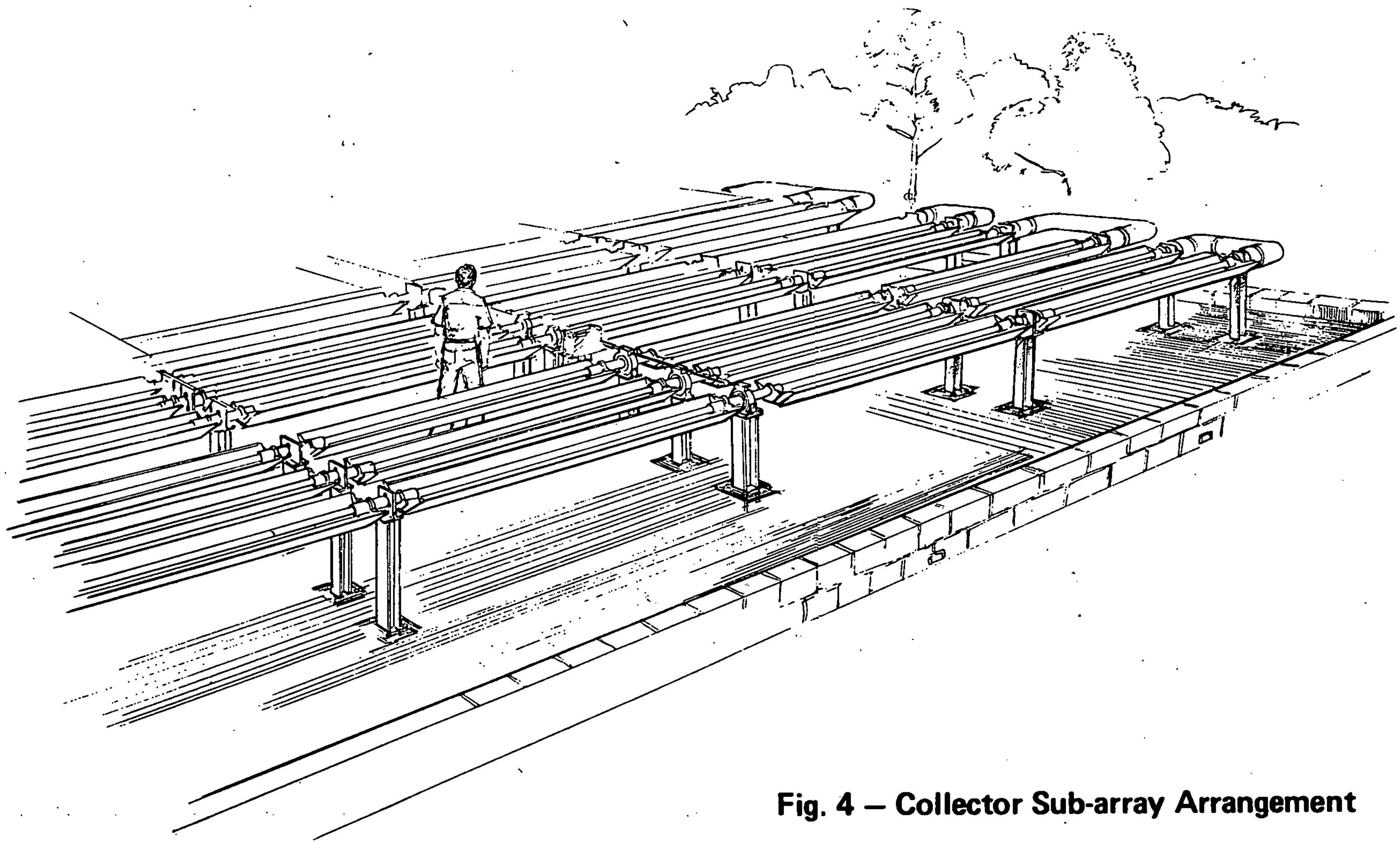

Fig. 4 — Collector Sub-array Arrangement

INVITED PAPERS

PHILADELPHIA, PENNSYLVANIA

Keynote Address
by
Mr. Lawrence Levy
President, Northeast Solar Energy Center
Northern Energy Corporation
at the
U.S. Department of Energy's Regional Solar Updates
Philadelphia, Pennsylvania
July 29-31, 1979

It is indeed a pleasure and a privilege for me to be your Conference Co-Chairman at this important meeting sponsored by the Department of Energy (DOE), and to deliver this keynote address. The Northeast Solar Energy Center (NESEC) is also pleased to be your host for this Regional Update on solar energy.

The primary objective of my remarks this morning is to set the tone for this conference. A great deal of effort has gone into its preparation, and we have been fortunate in assembling an excellent group of speakers, panel chairmen, and panel and round table members. I know that this Update will furnish all attendees with valuable information on the progress of solar energy demonstration and data programs, as well as provide important insights on where future opportunities may lie in this growing field. I believe, also, that you will all recognize that solar energy has progressed from its status as reported at this same Regional Update last year.

I will not dwell on the current statistics about our energy situation, and how serious our domestic and international problems are because of our excessive dependence on oil, particularly foreign imports. I know that you are all familiar with those facts. I will say, however, that unless we find alternatives to our use of oil, in a reasonable time, these National problems will continue to multiply. It is my firm conviction that solar energy offers one very promising alternative, and it is this challenge that brings us all here today.

In the time allotted to me, I would like to briefly cover three principal areas. At the outset, I want to place very recent important events in the energy field into perspective, and give you my assessment of what they mean for the solar industry. Secondly, I want to describe the mission and responsibilities of the Northeast Solar Energy Center, and what we are doing to help bring about the commercialization of solar energy on an accelerated time scale. And lastly, I want to make some observations on advancing technology, and its potential effect on the contribution that solar energy could provide to our future energy picture.

There is little question that events of the past several weeks have placed a new focus on solar energy. I am referring to the President's message on solar energy of June 20, at the time he dedicated the solar hot water system on the White House; and his major address to the country of July 15 on the Import Reduction Program. Both of these messages are related, and have an impact on the future of solar energy, the solar industry and the consumer.

The importance of the June 20 message is that the President set a goal of 20% contribution for solar by the year 2000. It should be recognized that this message and its stated objective were an outgrowth of the Domestic Policy Review (DPR) which was started over a year ago by the White House. While one might argue that the goal should be higher, the significance of the message is that a goal -- albeit a "challenge goal" -- was set. This is the first time that any administration has postulated such a goal for solar energy, along with the outline of a program to help achieve it. The Import Reduction message reaffirms the statements made in the earlier message, and provides additional information and recommended programs to implement the Solar Bank and tax credits for a variety of solar options. One of the main themes of the Import Reduction message is conservation, which has to be the hand in glove partner of solar. In view of these initiatives, I believe that we are beginning to see, at last, a building momentum for solar energy.

A breakdown of the 20% goal for the country, by solar option, was formulated by the Office of the Assistant Secretary for Policy and Evaluation of the Department of Energy. I have taken this breakdown and divided the individual National solar option goals by a factor of 4 for the Northeast. The Northeast Region, by definition, consists of nine States: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont. The population of this Region is about 50 million people, or slightly less than one-quarter of the total population of the country. Although there are other factors to consider in apportioning specific contributions by solar option, at this point dividing the total goals by four is certainly realistic. Figure 1 shows the National and Northeast Region goals. You will note that for a projected 95 to 100 Quad (10^{15} Btu's) energy demand for the year 2000, as specified by DOE, the total National solar goal is 18.0 Quads. For the Northeast, our share of this goal would be 4.50 Quads.

As you can see from this figure, the total of 18 Quads includes both low and high head hydroelectric. For my presentation today, I will omit any discussion of hydro, and so, if you subtract out that particular option, the remaining solar technologies would total 3.425 Quads for the Northeast.

I thought that it would be interesting, as well as useful, to see what those projected solar Quad goals mean in terms of equipment or systems installed by the year 2000. I did some calculations on all of the options (excluding hydro), and, of course, made some assumptions for several important factors. These included the average insolation in the Northeast; the performance of the various technologies or options as we know them today; and for the solar thermal options, the average number of square feet of collector that might be

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Corporation
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SOLAR GOALS FOR YEAR 2000

20% OF 95 TO 100 QUAD SUPPLY

SOLAR OPTION	U.S. TOTAL* QUADS	NORTHEAST SHARE QUADS
HYDRO (HIGH AND LOW HEAD)	4.3	1.075
BIOMASS	5.4	1.35
RESIDENTIAL HEATING AND COOLING	2.0	0.5
PASSIVE	1.0	0.25
AGRICULTURAL AND INDUSTRIAL PROCESS HEAT	2.6	0.65
WIND	1.7	0.425
PHOTOVOLTAIC	1.0	0.25
TOTALS	18.0 Q	4.50 Q

*REF.: PRESIDENT CARTER'S SOLAR ENERGY MESSAGE OF JUNE 20, 1979

BREAKDOWN AS RELEASED BY OFFICE OF ASSISTANT SECRETARY, POLICY AND EVALUATION, DOE

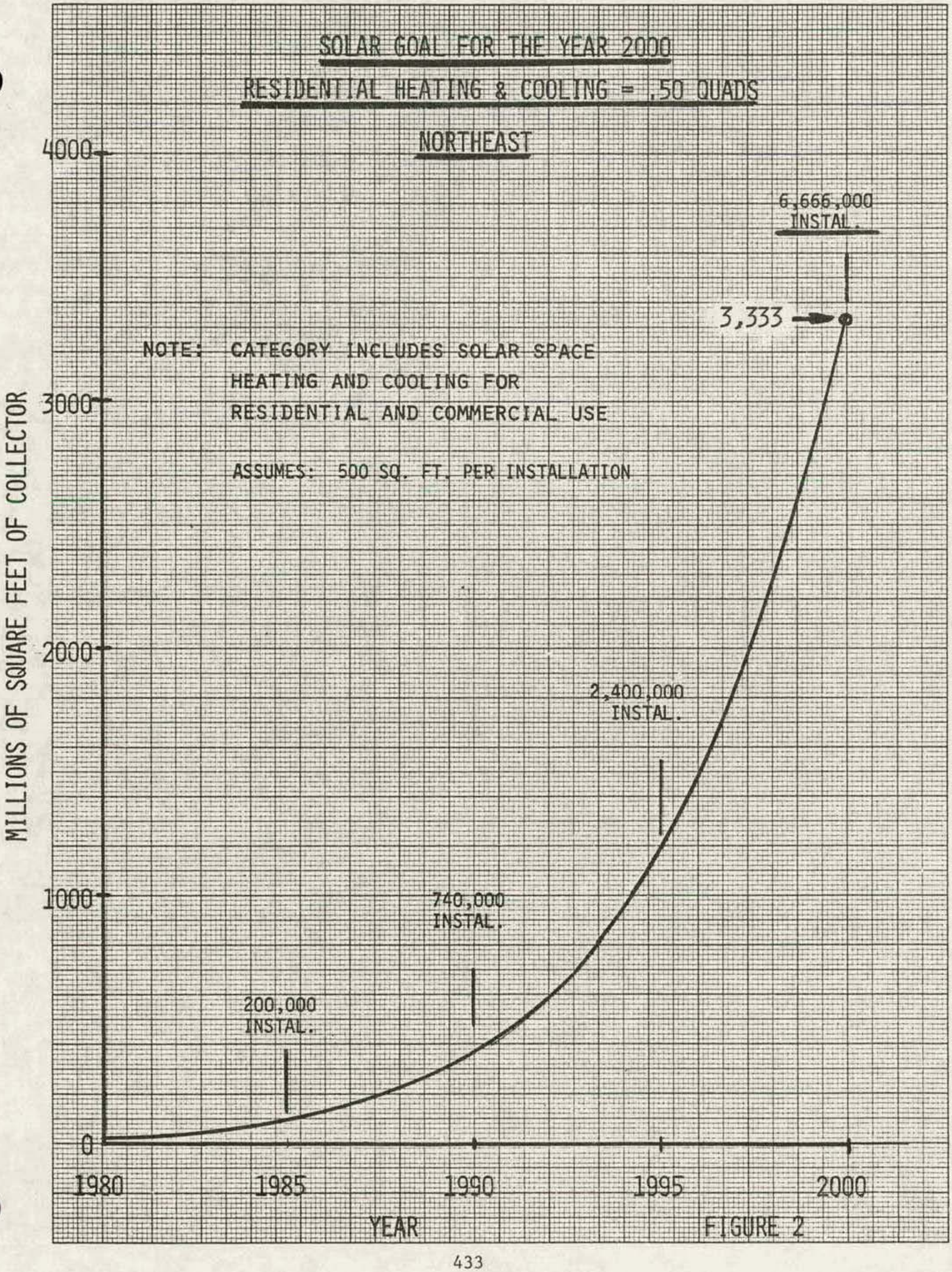
FIGURE 1

required for various specific types of installations. My main objective was to get a picture of the magnitude of what these goals mean, and while the calculations were not performed on a computer, realistic assumptions based on empirical or established data were used throughout. A more detailed analysis might refine the results somewhat, but my intuitive feeling is that they would not change significantly. I must also stress that the calculations were performed based upon present day technologies and associated installation costs.

The first option considered was Residential Heating and Cooling, with a Northeast goal of 0.5 Quads. This category also includes commercial usage and represents the total of all solar space heating and cooling and hot water. Figure 2 shows a plot of millions of square feet of collector versus calendar years from 1980 to 2000. The plot indicates that in order to achieve 0.5 Quads, there would have to be 3,333 million (or 3.33 billion) square feet of collector installed by the year 2000. Assuming an average of 500 square feet of collector per installation, we would have 6,666,000 installations by that time. The figure of 500 sq. feet per installation reflects commercial usage in the mix of installed systems. I have also spotted on the curve the number of installations required in five-year intervals beginning in 1980. At an installed cost of about $35 per square foot -- and in 1979 dollars -- we are looking at potential sales of over $116 billion for this category for the twenty year period beginning in 1980 and ending in the year 2000. There is no question that this is a significant amount of square feet and related number of installations.

Similar calculations were performed for the other solar options, and the next one, Figure 3, is for biomass -- which is wood burning. For biomass, in order to achieve the goal of 1.35 Quads, it would take 45 million cords of wood per year to generate that much energy. While this seems like a tremendous amount of wood, if those cords -- which measure 4 ft. wide by 8 ft. long by 4 ft. high -- were placed side by side, they would cover an area of only 51.65 square miles. As the figure indicates, the forested area of the nine Northeast States is over 100,000 square miles. The Northeast could easily produce that amount of wood, but the problems are in the management of the forests, the lumbering operations and in transportation and delivery to user sites.

The solar goal for wind energy for the Northeast is 0.425 Quads. In order to get an idea of the number of wind machines required to generate that much power, it was necessary to assume a mix of wind machine sizes which were: 50% at 5 KW, 25% at 25 KW, 15% at 200 KW and 10% at 1 MW. Figure 4 shows the results, and it is interesting to see that with the assumptions made, there would have to be 170,800 wind machines by the year 2000 in the mix of sizes just described. The 5 KW machines would probably be for residential or special uses; the 25 KW might be utilized in farm applications; the 200 KW for small communities or industrial complexes; and the large 1 MW might be associated with utility or large industrial complex usage.



SOLAR GOAL FOR THE YEAR 2000
RESIDENTIAL HEATING & COOLING = .50 QUADS
NORTHEAST
NOTE: CATEGORY INCLUDES SOLAR SPACE HEATING AND COOLING FOR RESIDENTIAL AND COMMERCIAL USE
ASSUMES: 500 SQ. FT. PER INSTALLATION
MILLIONS OF SQUARE FEET OF COLLECTOR
4000
3000
2000
1000
0
6,666,000 INSTAL.
3,333
2,400,000 INSTAL.
740,000 INSTAL.
200,000 INSTAL.
1980
1985
1990
1995
2000
YEAR

FIGURE 2

Northern Energy Corporation
Northeast Solar Energy Center

SOLAR GOAL FOR YEAR 2000

NORTHEAST

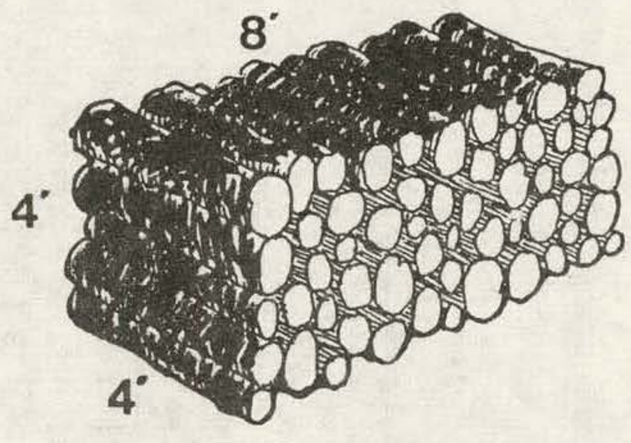
BIOMASS

1.35 QUADS MEANS 45 MILLION CORDS OF WOOD

434

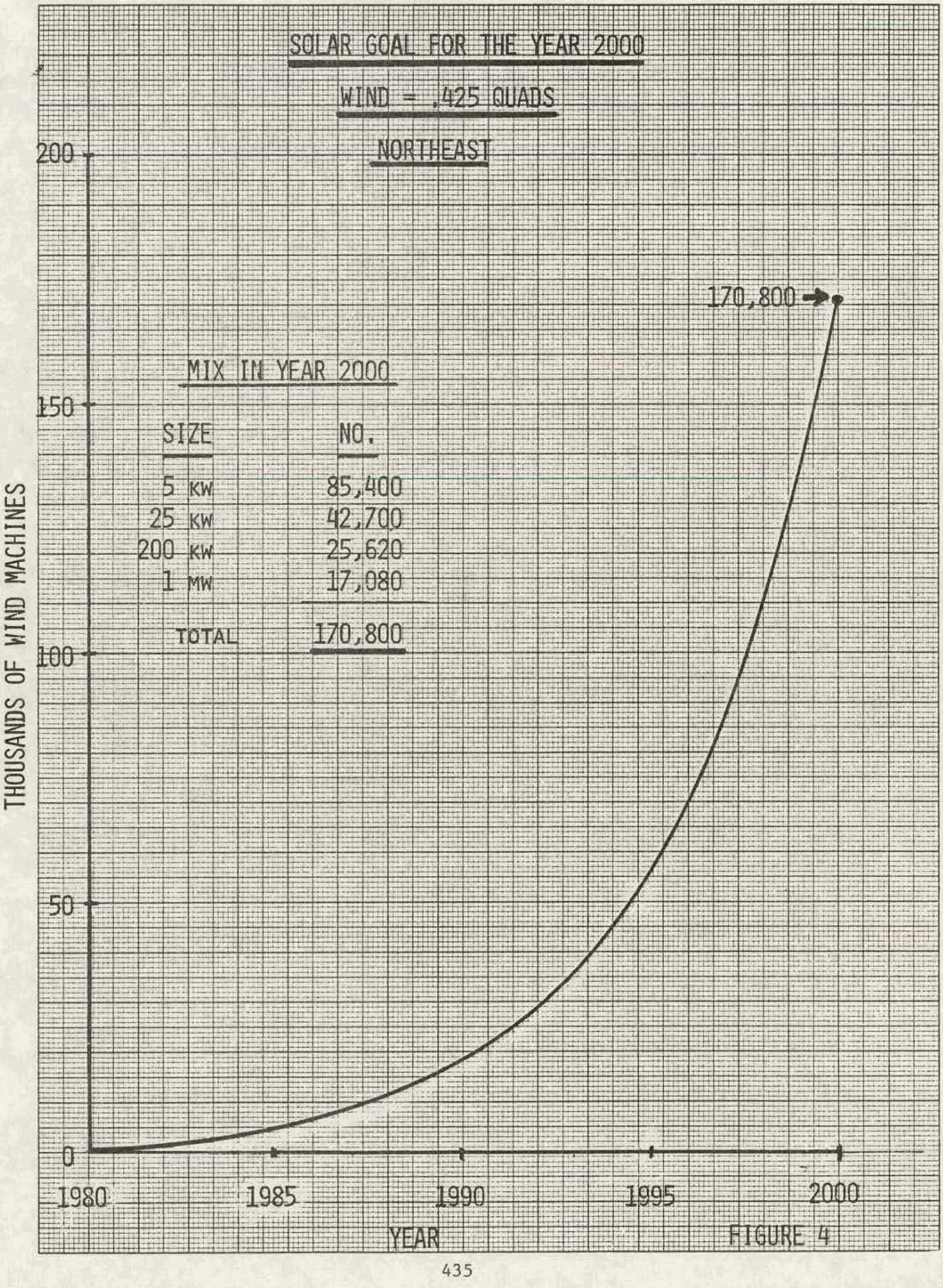
THIS NUMBER OF CORDS PLACED SIDE BY SIDE

COVERS AN AREA = 51.65 SQ. MILES



NOTE: THE FORESTED AREA OF 9 NORTHEAST STATES IS OVER 100,000 SQ. MILES

FIGURE 3



SOLAR GOAL FOR THE YEAR 2000
WIND = .425 QUADS
NORTHEAST
170,800
MIX IN YEAR 2000
SIZE
NO.
5 KW 85,400
25 KW 42,700
200 KW 25,620
1 MW 17,080
TOTAL 170,800
THOUSANDS OF WIND MACHINES
200
150
100
50
0
1980
1985
1990
1995
2000
YEAR

FIGURE 4

I will not describe the details of the calculations made on the other options, but will simply show a summary of the results in Figure 5. You will note that in addition to the options just described, the calculations indicate that for Passive, there would have to be 3.10 billion sq. ft. of glazing; for Agricultural and Industrial Process Heat, 3.61 billion square feet of collector; and for Photovoltaics, 378 million square feet of solar cells.

For just the solar thermal options of Residential Heating and Cooling and Agricultural and Industrial Process Heat, we are talking about a total of 6.71 billion square feet of collector by the year 2000. That represents a market of $234 billion over the next twenty years. For the Passive option, at about $20 a square foot installed for glazing material, we are talking about $62 billion, exclusive of other materials used in passive design. While we are just at the beginning of the growth of the solar industry, achievement of these goals indicate huge potential markets for solar equipment in the years ahead. There is little question in my mind, therefore, that major solar business opportunities do exist.

We are now faced with the problem of how to achieve the goals and thereby bring about the more rapid utilization of these needed energy sources. This leads me to a brief description of the Northeast Solar Energy Center, which is a division of Northern Energy Corporation, a not-for-profit company located in Cambridge, Massachusetts. The Center is operated under contract to the Department of Energy, and reports to the Office of the Assistant Secretary for Conservation and Solar Applications. We are one of four such Regional Centers around the country, and our nine-State Northeast Region consists of the States previously mentioned. Our mission is to help bring about the more rapid commercialization of solar technologies and conservation integral to solar applications. In effect, we are utilizing Federal funds to stimulate the private sector to develop solar energy products, processes and services, and to remove the barriers to consumer use of these technologies. In carrying out this mission, we work closely with the member States of the Region, and all elements of the private sector. We must recognize that the commercialization of solar energy, and the attainment of the goals previously discussed will be achieved by the private sector, but this task cannot and will not be accomplished without the support of the Federal Government and the active participation of the States.

Since the beginning of our implementation phase in May, 1978, we have been engaged in an increasing number of activities at the Center that we believe can contribute to the utilization of solar energy on a time scale that will be much shorter than if left to normal market forces. Our primary project activities are currently focused in the solar hot water and passive solar areas. We are also now beginning commercialization oriented projects in solar space heating, agricultural and industrial process heat, biomass (wood), wind energy and photovoltaics.

Northern Energy Corporation
Northeast Solar Energy Center

SOLAR GOALS FOR YEAR 2000

NORTHEAST

SUMMARY

OPTION	QUADS	ALTERNATIVE REQUIRED
BIOMASS	1.35	45 MILLION CORDS OF WOOD
RESIDENTIAL HEATING & COOLING	0.50	3.33 BILLION SQ. FT. OF COLLECTOR
PASSIVE	0.25	3.10 BILLION SQ. FT. OF GLAZING
AGRICULTURAL & INDUSTRIAL PROCESS HEAT	0.65	3.61 BILLION SQ. FT. OF COLLECTOR
WIND	0.425	170,800 WIND MACHINES (5 KW TO 1 MW)
PHOTOVOLTAICS	0.25	378 MILLION SQ. FT. OF SOLAR CELLS
TOTAL	3.425 QUADS	

USE OF THESE ALTERNATIVES WOULD SAVE:

570 MILLION BARRELS OF OIL EQUIVALENT PER YEAR

FIGURE 5

The Center has four operating divisions that are equally important to the total process of commercialization, and their names really define this process: Planning and Assessment, Industrial Development, Communications and Technology. In our Planning and Assessment Division, we are conducting an on-going assessment of the resources of the Region that can be brought to bear on assisting the commercialization process in an environmentally acceptable manner. In addition, we are continually surveying the energy needs of the Region to see where it may be possible to utilize solar systems, and thereby reduce our dependence on oil. We are also engaged in assisting DOE with its planning efforts in the solar area.

In our Industrial Development Division, we are providing technical and marketing assistance to small companies and individual inventors, and finding ways to bring venture capital and banking sources together with the developers of solar technology. In addition to working with the solar industry and addressing the problems of the consumer, we are trying to stimulate other sectors of the economy important to the commercialization process including: bankers, insurers, appraisers, labor union officials, educators and utility personnel.

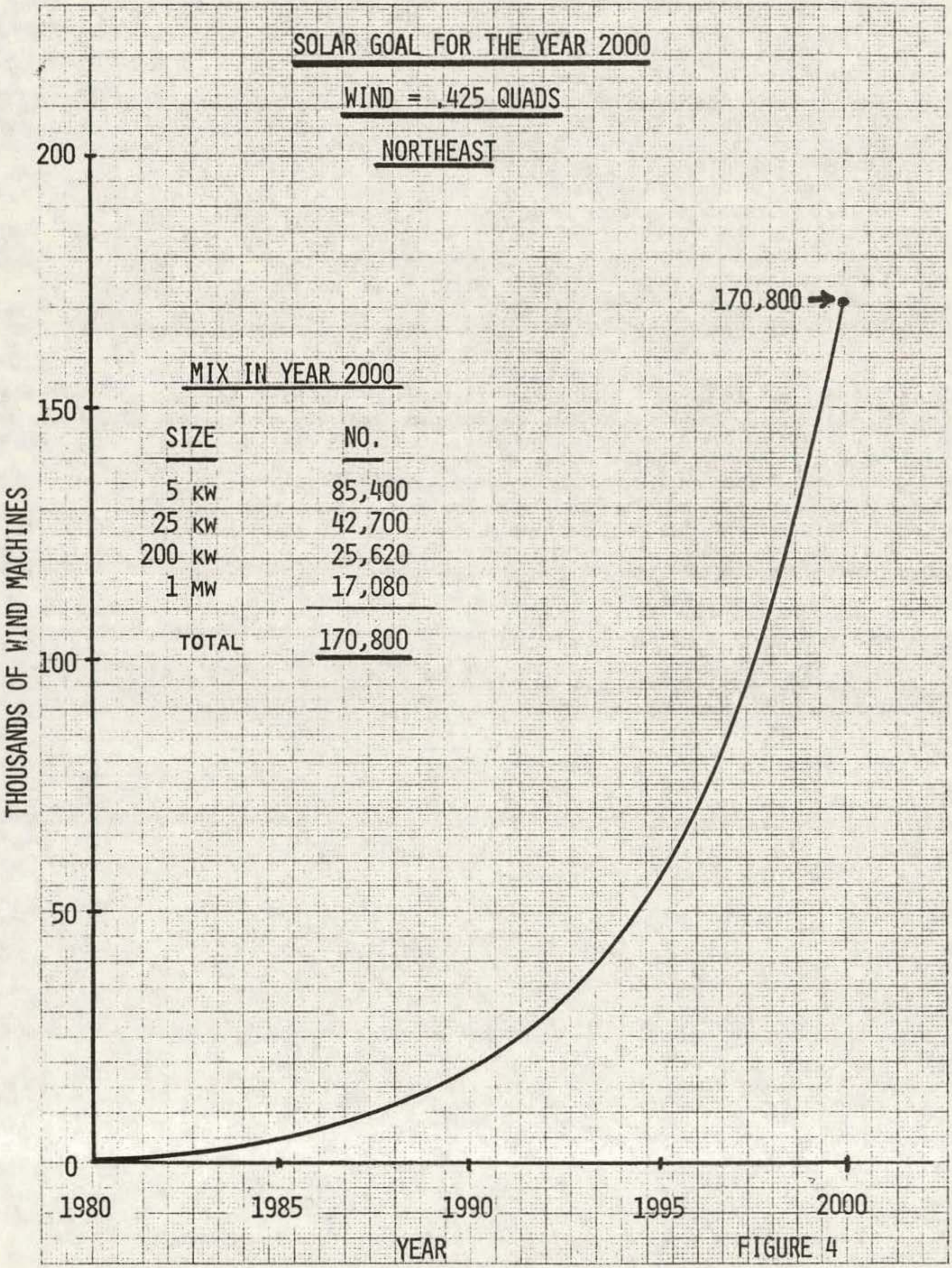
In our Communications Division, we are conducting a number of outreach activities aimed at supplying technical and related information on solar energy to the developer community and to consumers. We also have an active education program in which we work with State agencies and others in developing solar curricula for grade schools, high schools, vocational schools and community colleges. We are conducting public information programs, workshops and are participating in trade shows with the objective of better acquainting the public at large with the potential of solar energy. We also maintain an expanding solar energy library which is open to the public.

Our Technology Division provides the sound technical base for all of our activities. Our computerized data bank for the Region is a part of this Division's operation, and its capacity is growing every day. In addition, we provide systems and engineering support, both within the Center and to the solar community, to those technologies that offer maximum short-term potential for commercialization, and which fit our Regional requirements. I should perhaps mention that we have not been involved in the demonstration and solar data programs directly, but are monitoring this activity closely as part of our overall mission.

Our professional staff includes economists, architects, lawyers, computer scientists, educators, engineers and specialists in marketing, finance and business. We are an action-oriented organization whose objective is to help create a solar energy industry, and its infrastructure, as rapidly as possible.

As far as advancing technology is concerned, I am quite convinced that it will have a dramatic and positive effect on the products and processes that we will see in the solar energy field over the next twenty to twenty-five years. In developing this point, it is illuminating to see what products or systems we find in large scale commercial usage today, that did not exist twenty-five years ago. In the electronics field, we have the transistor, integrated circuits, digital computers, hand held calculators -- and even television. In optics, we have the Xerox copier, Polaroid instant colar stills and movies, and the telecopier. In aviation, we have commercial jet airliners. Who in this room could have predicted even half of these developments twenty-five years ago? The year 2000 is slightly more than 20 years away. What I am saying is that I do not believe for a minute that there will not be similar technological developments and advances in the solar energy field by then. Given the proper resources, I am convinced that solar energy in all of its currently known options, and in some that have not even surfaced, will make a significant contribution to the future energy supply of the country.

In conclusion, I would like to say that there is little question that if we do not succeed in finding alternatives to our high dependence on oil, our political, economic and defense viability as a Nation will begin to disintegrate in the years ahead. We are truly in a desperate race to regain our energy independence. I am confident that we can succeed, but to do so, it is mandatory that an all-out effort be made to mobilize the technological and management resources of the country. This mobilization must include all those who have a contribution to make such as the individual inventor, small and large industry, and universities. It will require the establishment of new, novel and flexible relationships among the Federal and State governments and the private sector. Above all, this mobilization must include mechanisms for cutting through red tape, so that important contributions can be made on a timely basis. Since this is not now the case, herein lies one of the great institutional challenges of all times for our country and its people.


SOLAR GOAL FOR THE YEAR 2000
WIND = .425 QUADS
NORTHEAST
MIX IN YEAR 2000
SIZE
NO.
5 KW
85,400
25 KW
42,700
200 KW
25,620
1 MW
17,080
TOTAL
170,800
170,800
THOUSANDS OF WIND MACHINES
200
150
100
50
0
1980
1985
1990
1995
2000
YEAR
FIGURE 4

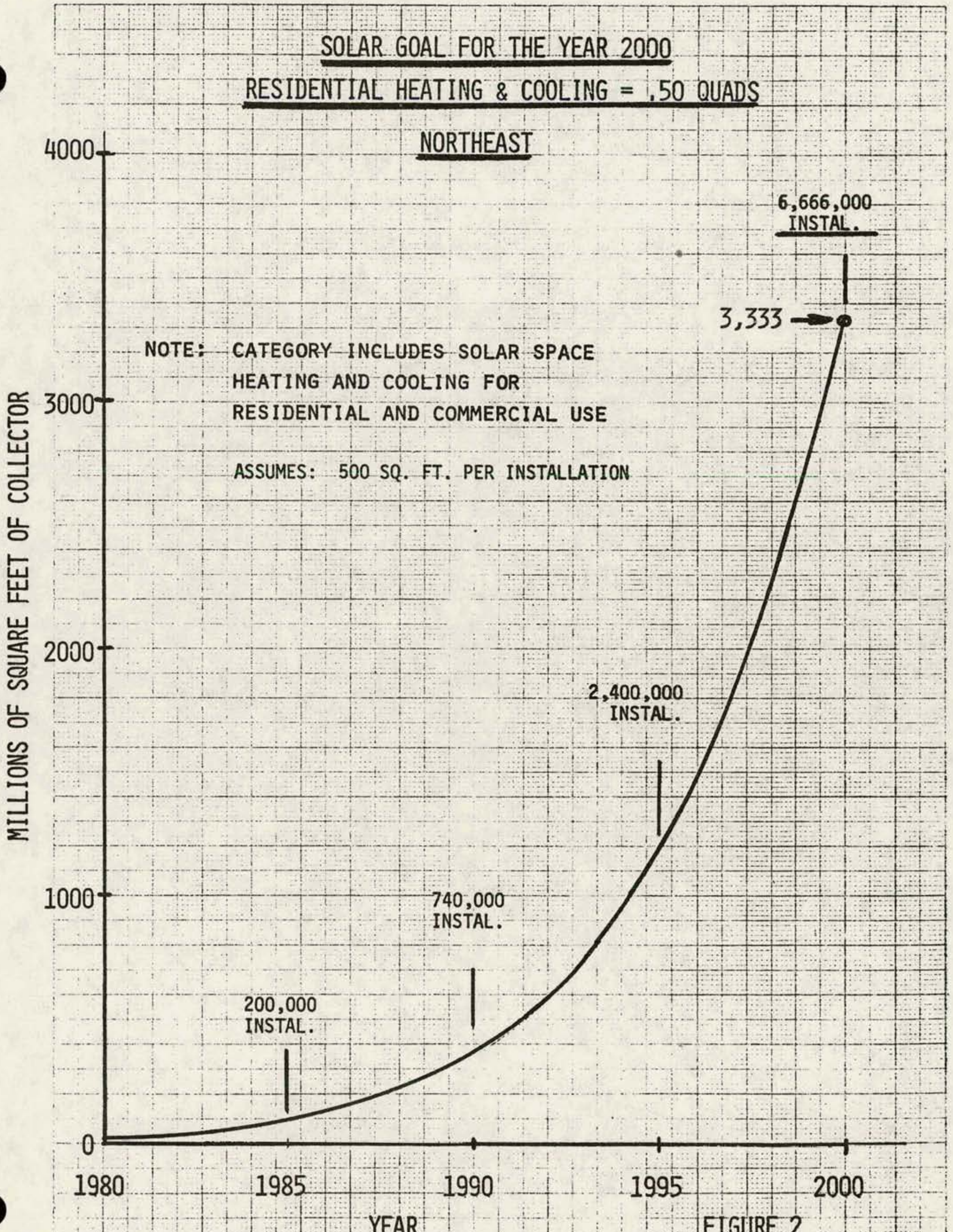

SOLAR GOAL FOR THE YEAR 2000
RESIDENTIAL HEATING & COOLING = .50 QUADS
NORTHEAST
6,666,000 INSTAL.
3,333
NOTE: CATEGORY INCLUDES SOLAR SPACE HEATING AND COOLING FOR RESIDENTIAL AND COMMERCIAL USE
ASSUMES: 500 SQ. FT. PER INSTALLATION
2,400,000 INSTAL.
740,000 INSTAL.
200,000 INSTAL.
MILLIONS OF SQUARE FEET OF COLLECTOR
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
YEAR

FIGURE 2

An Overview of Six HUD Solar Demonstration Projects in New England

by

James G. Serdy

This paper and visual presentation reviews six completed solar demonstration projects which were awarded funding grants under the Department of Housing and Urban Development Residential Solar Demonstration Program. These projects include new construction building integrated and retrofit applications, both low and high rise. Solar Design Associates of Canton, Massachusetts was responsible for the energy systems design and engineering on these projects.

"Forest Edge Condominiums", the first five unit cluster of a 33 unit solar residential development located on the south face of Birch Hill in North Conway, New Hampshire was awarded a grant under Cycle 2 of the U.S. Department of Housing and Urban Development's Solar Residential Demonstration Program. The builder/developer was Kearsarge Building Co., Inc., Main Street, North Conway.

Energy conscious design was first priority on this project. Among the principles employed were: heavy foamed in place insulation, a positive vapor/infiltration barrier, minimum north wall glass, party walls, large south facing walk-out sliding glass window walls for passive solar gain, earth sheltering to the 2nd floor on the north side, air lock entrances and a long sloping north roof for wind deflection.

The south roof is pitched at latitude $+10^{o}$ to receive 40 Daystar model 21-A flat plate solar collectors. A common 1,000 gallon steel storage tank serves all units on a first call basis through water to air heat exchangers located in the supply ducts to the individual unit gas fired hot air furnaces. Domestic hot water preheating is accomplished through a heat exchange coil in the storage tank.

Heat transfer from the solar collectors is accomplished through the use of a non-toxic 60/40 glycerin/water solution (Daystar Solargard P) and a single separation heat exchanger.

Overtemperature protection for the Daystar polycarbonate "heat trap" inner glazing (model 21-A collector) required the use of external heat dump panels in a thermal siphon configuration. These units were later found by the manufacturer to be inadequate, and a stand-by power system was installed by Daystar to insure continuous circulation of coolant. Secondary protection is provided by a continuous purge of the system by city water in the event that a temperature/pressure relief valve opens. However, the anti-freeze coolant would be diluted in such an event.

The project was completed in late summer 1978. Very good performance was reported by the developer for the first winter.

Also in North Conway, New Hampshire is a garden apartment complex development located at the foot of Cathedral Ledge. The first 12 unit cluster of a proposed 112 unit solar residential development by Forest Park Associates received a construction award under Cycle 3 of the U.S. Department of Housing and Urban Development's Solar Residential Demonstration Program for the site fabrication of a 5,000 sq.ft. roof integrated hot air collector system.

The 60^{o} south roof was framed 24" O.C. with select 2 x 12 rafters treated with urethane to prevent outgasing and for weather protection during construction. Pre-cut 2" foil faced isocyanurate rigid insulation boards resting on furring strips provide a high temperature barrier to the house and a bearing surface for the "DIY-SOL" selective surface corrugated aluminum absorber plates.

A double glazed panel of 40 mil. fiberglass reinforced plastic and 1 mil. teflon was factory assembled on an aluminum frame with a 2" extension flap on the outer glazing to allow shingling of horizontal joints. The panels span between rafters and are held in place with aluminum "T" battens anchored to the rafters with gasket head lag bolts. A bead of silicone construction sealant is applied between the glazing panels and battens and around the insulation panels to insure a weather and air seal for this combined roof collector system.

Collectors are manifolded to each unit and air is circulated in a single pass configuration to a rock bin in the basement or directly to the dwelling. A differential controller, a motorized damper and a two stage thermostat are all that is needed for the operation of the system. A manually operated ridge vent is opened during the summer to reject un-wanted heat by thermal siphoning.

This project was completed during the summer of 1978. No performance data is yet available.

The Hancock House, 45 School Street, Quincy, Massachusetts was awarded a Cycle 3 H.U.D. residential solar demonstration grant. This 92 unit high rise elderly housing complex is an all electric building completed in 1972.

The building orientation and non-load bearing roof construction required diagonal mounting of the collector array on long span tubular steel space frame trusses anchored into the perimeter masonry walls. These special structural requirements represented a large protion of the total project cost.

97 Daystar 21-A flat plate solar collector panels piped in reverse return arrays are series parallel connected in a single pumping loop served by a

parallel pair of 1/6 HP centrifugal pumps to insure continued circulation in event of a failure of one of the pumps. The mechanical room and 1,000 gallon potable water storage tank are located in a roof top penthouse to minimize pumping requirements and heat loss.

Monitoring during the first year of operation (77-78) indicated a 70% annual contribution and an actual savings of $7,375.

The solar system at Hancock House was dedicated on "SUNDAY" May 1978 with Senator Edward Kennedy in attendance.

Mission Towers, 180 Water Street, Haverhill Massachusetts is an all electric H.U.D. financed elderly housing project constructed in 1973. The 117 unit 9 story building faces due south.

Funding for a solar domestic hot water system was awarded on a cost share basis in late Spring of 1972 under Cycle 4 of the Department of Housing and Urban Development Residential Solar Demonstration Program.

107 flatplate solar collectors spanning the non-load bearing roof on tubular steel trusses were accommodated. Because of the high cost of the structural interface between the solar collector support trusses and the non-load bearing roof system, engineering and economic trade-offs had to be made resulting in the location of the equipment room on the ground level.

Systems components include a 2,000 gallon solar storage tank, a single separation shell and tube heat exchanger, and daystar 21-B flat plate solar collectors with integral over-temperature control.

The solar system at Mission Towers became operational in Spring 1979 and on clear days in May was supplying 100% of the building's domestic hot water needs. The system is expected to contribute 75% of the hot water requirement of the building at an annual savings of $8,000.

On June 10, 1979 Senator Paul Tsongas (D. Mass.) opened the dedication ceremony at Mission Towers with an address on energy policy.

Eastern Nazarene College, 23 East Elm Avenue, Wollaston, Massachusetts received a Cycle 4A funding award through the Residential Solar Demonstration Program administered by H.U.D. for the solar retrofit of a 160 student dormitory residence.

An active flat plate solar collector array was mounted above the roof deck using the parapet wall for support and ballast against negative wind loading.

The solar system interface is with an existing campus central steam system, and a general up-grading of that equipment is part of the overall energy program at Eastern Nazarene.

The system has just recently been completed and is operating well.

Granite Place, 125 Granite Street, Quincy, Massachusetts is a new 270 unit high rise elderly housing project which was designed with solar in mind.

Single loaded corridors on the top floor of the east/west wings of the building made it possible to relate 6,500 sq.ft. of flat plate collector harmoniously with the structure and design of the building.

Granite Place received a Cycle 4 grant from H.U.D.'s Residential Solar Demonstration Program to cost share in this installation.

The building is also equipped with a 3.5 KW peak tracking photovoltaic array which provides power for the pumps and controls of the flat plate solar system.

A micro-processor control system is being installed to maximize the potential for domestic hot water load management at Granite Place.

The solar energy system at Granite Place provides nearly 100% of the domestic hot water heating requirements during the summer months with less contribution during the winter for an annual contribution of 75% - 80%. The system has performed very well since start up in March of 1979 and there have been no problems.

In summary, we have felt that the H.U.D. residential solar demonstration program has been vitally worthwhile in establishing the case for solar energy and we have been pleased to participate.

Start-up Experience and Early Operation of a College Dormitory Solar Water Heater - The User's Point of View

Edward N. Clarke and Frank R. Swenson

Introduction

Worcester Polytechnic Institute (Worcester, Massachusetts) has a retrofit solar water heater serving a dormitory housing sixty students plus the college infirmary. The solar system was activated for the first time on December 16, 1977 and has been operational since that time. In the spirit of helping others to avoid future problems with solar systems, this paper will concentrate on problem solving experiences.

System Description

With 28 collectors and four heat dumps in a single array, the WPI system may still be the largest solar water heater in Central Massachusetts. The collector loop contains 36 gallons of a nominal 60% glycerol/40% water antifreeze mixture. An intermediate loop interconnects the system through two heat exchangers. Storage of hot water is provided by 8-120 gallon tanks for a total storage of 960 gallons. The system has a single operating mode. The three pumps in the system are controlled by a single differential thermostat which senses the temperature difference between the storage tank and a collector outlet. If this temperature difference exceeds $30^{o}F$, all three pumps are turned on, and heat is transferred from the collector to the domestic water. The collectors are inclined at 45^{o} from the horizontal roof surface, and face 8^{o} west of south in a normal alignment with the building. The original electric water heater is incorporated into the system for raising the water temperature when needed.

System Problems and Solutions

System problems fall into the general categories of construction cost overruns, schedule slippage, inadequate component performance, component failure, and chronic problems. Each of these will be discussed in turn.

Construction Cost Overruns

Table 1 shows a summary analysis of construction costs. Cost of manufactured collectors and other hardware, and the costs of plumbing were on target. The largest cost overrun concerned the fabrication, assembly and attaching of the support structure to the roof. Fabrication of the support structure (off-site) was somewhat more costly than estimated, but the costs of on-site assembly of that structure and the roof attachment were virtually ignored in the original estimates and in reality were very labor intensive and expensive.

Table 1

Analysis of WPI's Dormitory (Stoddard C) Solar Water Heater Cost*

	Budget	Cost	Excess over Budget
All plumbing except collector installation; includes piping, pumps, controls, heat exchangers, water storage tanks, etc.	11,100	11,100	-0-
Solar collectors, heat dumps and related hardware	9,373	9,373	-0-
Fabricate and erect collector support structure for retrofit	5,000	13,115	8,115
Collector installation	400	2,631	2,231
Design of support structure	1,000	2,300	1,300
Control and pump wiring	500	831	331
TOTAL	27,373	39,350	11,977

* does not include cost of solar design work.

Collector installation proved to be more expensive than estimated for several reasons. Collectors delivered had bolt hole separations 1" different from that shown on the vendor's original spec sheet. Additional metal hardware had to be fabricated in order to attach the collectors to the support structure. The problems of lifting collectors into position on a large array had not been thought through carefully, and it was required to construct special aluminum ladders to use for the array assembly.

The overall lesson to be learned concerning construction of a solar system is that the labor intensive, less exotic aspects of constructing solar systems must receive adequate attention and planning.

The early design analysis suggesting that one large array was less costly than several roof level rows of collectors was illusory. Any saving in plumbing cost was ultimately consumed by costly fabrication of the single large support structure and on-site assembly. Maintenance on one large array is a continuing more costly and more difficult problem.

Schedule Slippage

The original schedule called for the solar system to be operational in late August 1977. Delivery of the support structure was late and its assembly on the roof was not started until October 1977. The system was finally turned-on for the first time on December 16, 1977. This late turn-on date might have been acceptable if the system had been free of problems. In fact, there were serious start-up problems (described below) requiring that we wrestle with those problems on the roof during the months of January, February, and March 1978. Weather-wise those were bad months in New England to be working with the above-roof problems on a new solar system.

The design, construction, and early operation of the solar water heater had become a shared responsibility of the designer, the project-administrator, and the separate buildings and grounds organization. No single person had been assigned complete responsibility and authority for getting the job done. There was no general contractor.

The lesson to be learned, of course, was that even for a modest solar project of this size, a clerk-of-the-works or a general contractor should have been assigned. This was the first solar system for all of the sub-contractors and on-site/off-site fabricators and assemblers. Under these circumstances, responsibility for costs and schedules, and corresponding authority should have been in the hands of a knowledgeable construction manager.

The other lesson to be learned is to avoid turning on a new solar system during December, January, or February in New England. If completion of construction does slip to early Winter, be patient and wait until Spring before turning on the system.

Inadequate Component Performance

The most serious single shortcoming of the installed system was the inability of the heat dumps to protect the collectors from overheating. Vendor design guidance had suggested that one heat dump would protect a row of ten collectors. In fact, the WPI design conservatively chose one heat dump per seven collectors. The design did not provide adequate protection, and allowed the top two rows to overheat, with resulting damage to the collectors. Overheating caused melting of the top row 257°F plug with subsequent loss of antifreeze. The system had operated with collector make-up-water valve closed for fear of potential freeze damage during December, January, and February. We believe that human error in failing to reopen a water inlet valve to loop #2 (intermediate loop) allowed a slow deterioration of heat transfer in heat exchanger #1 (collector loop to intermediate loop) and subsequent overheating of the collectors. In a separate event, the pump in the collector loop failed soon after the system was activated. Cloudy weather and quick replacement of the pump avoided possible damage to the collectors.

Several cycles of 257°F plug melting/antifreeze loss/plug replacement/antifreeze replacement led to frustration and agreement among all parties to eliminate the meltable plug. However, this action is something like that of the frustrated home owner replacing electrical fuses that keep popping and finally using a copper penny only to have the house burn down. In WPI's case, removing the fusible plug did eliminate the winter problem. During the low demand period in August, however, antifreeze found an exit by flowing through the water inlet valve (open for the summer) in the reverse direction, thence through a relief valve in the basement, and into a basement drain. The latter failure mode was discovered in October 1978 after a routine check of antifreeze strength. The collectors were found filled with nearly pure water, and required a new refill with antifreeze for the Winter of 1978-79.

The lesson to be learned is that one should really be concerned about stagnation, low demand periods, and potential overheating of collectors. One must assume that future customers will get a better deal on overheat protection.

Component Failure

The differential thermostat controller was a puzzle from the beginning and finally failed. Initially, the controller seemed to do its job properly in turning the system's three pumps on and off when required. However, the operation took place with considerable (external) relay chatter during the turn-on period, and during the turn-off period. Relay chatter destroyed the relay points which had to be replaced within a few months. Yet we had been advised that the controller was behaving properly. Eventually, however, the controller stopped controlling the pump in the hot water loop. Replacement of the controller with a new model was accomplished. With the new model there is no relay chatter, and all three pumps go on-and-off as they should. That $60 frustration could have been eliminated much earlier.

The lesson to be learned is that early components may be inadequate, and that inexpensive components ought to be replaced as soon as better models are available.

Chronic Problems

The WPI collector array is made of collectors interconnected with mechanical unions. Small leaks develop. Tightening joints provides temporary help. But, as the array experiences the wide range of New England temperatures, small leaks once again develop. What one learns is that the large surface-to-volume ratio of solar collectors emphasizes the problems of small leaks. An 800 ft^2 array with only 36 gallons of antifreeze in the collector loop must be checked periodically for its liquid content and/or freeze protection.

The Future

WPI has a functioning solar water heater, and has learned to work with the system's shortcomings. The system's operation is about to be analyzed through a series of student projects. The system is now equipped with temperature sensors and flowmeters and will be interfaced through a microprocessor to a minicomputer. WPI is obviously very interested in the system's efficiency. There is some indication that the system may be providing a solar fraction considerably smaller than that predicted by the design.

SUMMARY

Table 2 is a summary of the problems discussed in this paper.

Table 2

System Problems in Approximate Chronological Order

	ITEM	COMMENTS
1.	Construction cost overrun (July - Dec. 16, 1977)	Largely from labor intensive support structure and collector array assembly.
2.	Schedule slippage (activation Dec. 16, 1977 instead of August)	Delivery of support structure was late. Project should have had a construction manager.
3.	Winter activation and first time operation of liquid system (Dec. 16, 1977 - Feb. 1978)	To be avoided in New England.
4.	Failure of pump in collector loop (prior to Dec. 28, 1977)	Quick replacement and cloudy weather avoided collector damage.
5.	Failure to reopen water inlet valve to intermediate loop, after work on pipe. (Dec. 28, 1977)	Careful and regular inspections of the system required during the first few weeks of operation.
6.	Melting of fusible plugs (Jan. 1978)	Heat dumps did not protect the plug location from reaching 257°F or higher temperatures. Irreversible loss of system integrity, and resulting loss of antifreeze.
7.	Collector damage from overheating (Jan. 1978)	Heat dumps did not protect distant points on the collector array from reaching 257°F or higher temperatures.
8.	Removal of fusible plug from top row. (March 1978)	Did not correct the basic problem. Antifreeze found a different flow path from the system, through a basement relief valve, during low demand period in August 1978.
9.	Slow failure of differential thermostat controller (Dec. 1977 - Sept. 1978)	Earlier replacement would have avoided frustrations including some Summer/Fall 1978 manual operations.
10.	Mechanical unions on collector array have chronic leaks (Summer/Fall 1978-Winter 1979)	Wide fluctuation of ambient temperatures in New England probably responsible.
11.	System efficiency is estimated lower than design target (Sept. 1978 - June 1979)	Damaged collectors in part responsible. Other factors yet to be determined.

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Northeast Solar Energy Center
HUD Solar Water Heating Program
Status Report: July 15, 1979

by

John F. Meeker
Program Manager

The Northeast Solar Energy Center (NESEC) is managed under contract to the U.S. Department of Energy by the not-for-profit Northern Energy Corporation. Established in 1977, NESEC was the first of four regional centers created by DOE to encourage the use of solar technologies to help meet the nation's energy needs. The Center's specific mission is to match the solar energy resources of the Northeast to the energy needs of the region while at the same time accelerating the commercialization of solar energy and lessening our dependence on foreign oil. To this end the Center established a Solar Water Heating Program Office on February 1, 1979.

PURPOSE

The intent of this paper is to report the progress of NESEC's Solar Water Heating (SWH) Program to date. For the short term, the 1979 installation season, we decided to concentrate on the awarding of the HUD $400 grants still unused in the Northeast. Since there were less than 5,000 active solar systems in place, and over 6,700 HUD grants available at the beginning of the installation season (March 1), our goal was to double the number of solar systems in place by November 30, 1979. (See Table 1 for the number of HUD grants available in the Northeast as of March 1, 1979.

Table 1

HUD Grant Status: March 1, 1979

State	Grants Allocated	Grants Installed	Grants Remaining
Pennsylvania	2,800	400	2,400
New Jersey	1,725	275	1,450
Massachusetts	1,375	190	1,185
New York	867	267	600
Connecticut	750	150	600
Rhode Island	250	45	205
New Hampshire	200	15	185
Vermont	150	20	130
TOTAL	8,117	1,362	6,755

Through this effort, we could generate $17 million (6,755 grants x an average system cost of $2,500) in sales of SWH systems in 1979, almost all of which would stay within the region.

Our original market development activity indicated that the initial installed cost of $2,500 was a barrier. The public was not aware that the HUD grants or the federal tax credits were available. To attain our goal we embarked on a three-pronged attack to inform the public that incentives were available which would reduce the initial cost to a reasonable level. We coordinated our efforts with industry, the states, and the media.

Industry

First, we met with the solar industry, both manufacturers and installation contractors, to discuss our campaign objectives and strategy. It was clear from those meetings that the industry was suffering financially. The 18-month delay in passing the federal tax credits into law had postponed the installation of thousands of SWH systems. The consumer was not going to purchase a SWH system if the $600-plus tax credit was not available. During 1978, several manufacturers and many more installation contractors were forced out of business due to inactivity.

The passing and signing into law of the federal tax credits in November, 1978 did not immediately help the situtation, as it coincided with the end of the installation season. Solar critics point to relatively few sales in the six-month period following passage of the law. However, since the installation season in the Northeast ends in early December, and does not begin again until March, relatively few sales could have been made. Due to the fact that it is impractical to work on a roof during most of the winter, several additional contractors left the business during that period to secure more lucrative work.

NESEC agreed to assist industry by holding marketing and installation workshops, giving lectures for consumers on SWH and supplying marketing materials to be utilized by solar firms. These included successful case histories of HUD grantees and promotional flyers, explaining the HUD grant program and tax credits.

The States

We also met with representatives of the eight Northeast region state energy offices participating in the HUD Grant Initiative to ascertain how we could best help them place the remaining grants in their states. The consensus was that some manpower and financial assistance would be made available.

To that end we assigned one NESEC staff member to work in the field with each of the participating states, two days per week. That action has enabled us to obtain specific information in each state on such things as target market areas, current installed system costs, active manufacturers and contractors, etc.

Media

All of the cooperation and coordination with industry and the states would be meaningless if we could not directly educate the consumer about the benefits of solar energy and the available incentives. We planned to accomplish this through an informed Speakers Bureau which would properly brief the media.

We trained a cadre of 24 people (16 NESEC staffers and eight state personnel) in effective methods of communicating with newspapers, radio and television.

We decided to brief the media through two press conferences announcing "Operation Sunpower." NESEC staffers would then seek in-depth follow-up interviews with media in selected target areas. By actively meeting with the media, we would be able to create a solar awareness in the consumers throughout our region.

ACCOMPLISHMENTS TO DATE

1. Identified Installed Cost (in the Northeast)

The average installed cost of a solar water heating system in our region during 1978 was $2,350. This figure was obtained through a sampling of 300 installations region-wide. During the first five months of 1979, the average installed cost from a sampling of 150 installations was $2,650. That cost can be broken down as follows:

SWH Package (Collectors, tank, heat exchanger, pump, and controls)	$1,600 ±
Miscellaneous Equipment (Piping, insulation, mounting equipment)	400 ±
Labor and Overhead	650 ±
TOTAL	$2,650

Notes: a. The installed costs range from $1,900 to $3,600 depending on family size, use patterns and location in our nine-state region.

b. It is fair to say that due to inflation and the rising costs of materials, the average installed cost for a domestic SWH system will approach $2,800 by September, 1979.

2. Identified Target Counties by State

Through the cooperation of the states, NESEC staffers have identified for industry the following counties in the eight states participating in the HUD initiative, where most of the solar sales have been made to date, as shown in Table 2.

Table 2

Target Counties by State

State	Counties	
Pennsylvania	Bucks	Chester
	Luzerne	Delaware
	Montgomery	Northampton
	Lehigh	York
New Jersey	Ocean	Morris
	Monmouth	
Massachusetts	Middlesex	Barnstable
	Plymouth	Essex
New York (only 13 counties participating)	Suffolk	Nassau
	Westchester	Duchess
Connecticut	Hartford	Fairfield
	New Haven	New London
Rhode Island	Washington	Newport
New Hampshire	Hillsborough	Rockingham
Vermont	Chittenden	

The methods used to identify these counties are the actual number of HUD grants installed and approved applications returned to the state energy offices through June 30, 1979.

3. Identified Manufacturers Pursuing Sales Region-Wide

While 70 or more manufacturers have had their SWH systems approved, for the HUD Initiative in most states, only 23 of these are receiving a significant amount of sales (15 or more installations as of June 30, 1979). Of those 23, four (4) are doing 54 percent of the business (1,102 out of 2,056), and three (3) have left the solar field. Table 3 lists manufacturers by state sales activity.

These figures are from records available in early July, 1979 at the various state energy offices. Actual installation figures and grant payments made are somewhat higher.

Table 3

HUD $400 Grant Sales Activity
(From Records Available through June 30, 1979)

Manufacturer	PA	NJ	MA	NY	CONN	RI	NH	VT	TOTAL
Grumman Energy Systems, Inc.	129	56	37	124	20	25	12	4	407
Sunworks, Inc.	36	74	44	50	81	13	14	1	313
Revere Solar & Arch. Products	34	59	38	46	5	10	3	4	199
Daystar Corp.	20	8	119	8	10	8	2	8	183
Heliotherm, Inc.	48	39	-	7	-	1	-	-	95
State Industries	65	12	-	5	-	1	1	-	84
Columbia Chase Solar	15	6	28	-	11	10	1	1	72
General Energy Devices*	24	11	12	12	-	6	-	-	65
Sunearth Solar Products	51	-	2	1	-	-	3	-	57
Lennox Industries, Inc.	34	6	2	1	-	-	2	-	45
Groundstar Energy Corp.*	-	4	4	9	23	-	1	1	42
Creighton Solar Concepts, Inc.	-	39	-	-	-	-	-	-	39
Mor-Flo Industries, Inc.	19	10	-	4	-	-	-	-	33
Practical Solar Heat, Inc.	33	-	-	-	-	-	-	-	33
American Solar Heat Corp.	-	-	-	-	31	1	-	-	32
InterTechnology Solar Corp.	20	7	1	1	-	-	1	-	30

Table 3 (Continued)

Manufacturer	PA	NJ	MA	NY	CONN	RI	NH	VT	TOTAL
PPG Industries*	25	-	-	-	-	-	-	5	30
Solar Processors, Inc.	-	-	3	-	10	10	-	-	23
W.L. Jackson Mfg. Co., Inc.	18	-	2	-	-	-	-	-	20
Solar Energy Systems, Inc.	3	16	-	-	-	-	-	-	19
Falbel Energy Systems Corp.	10	-	-	1	7	-	-	-	18
Solar Alternatives, Inc.	-	-	6	-	-	-	5	6	17
Dixon Energy Systems	-	-	15	-	-	-	-	-	15
OTHER (manufacturers with less than 15 systems installed region-wide	27	38	30	45	31	7	7	-	185
	611	385	343	314	229	92	52	30	2,056

* No longer manufacturing SWH systems

Notes: a. Clearly, four manufacturers are aggressively pursuing sales region-wide. They have built up a successful newtork of dealers/installers and are providing them with marketing assistance.

b. Others are securing a substantial share of the market in one or two states. To increase sales, solar manufacturers must improve their marketing efforts as well as improve the assistance to their dealers/installers.

4. Case Histories

a. The NESEC marketing department has assembled data and formulated case histories on 26 satisfied HUD grantees throughout our region. We have distributed thousands of these "case histories" at trade shows and speaking engagements as well as to various manufacturers and contractors.

b. One of our most successful efforts has been the HUD flyer shown as Figure 1. This piece of material has been distributed to 500,000 people. It has been picked up and distributed by newspapers, trade magazines, and been used in SWH brochures produced by other organizations, stimulating interest and awareness of SWH systems and the HUD grants.

Save 40% now... 50% every day with a solar hot water system

There's a 40 percent-off sale going on right now on solar hot water heaters. Solar water heaters that supply 40 to 60 percent of the energy needed to heat your family's hot water.

The sale is all part of the Federal Government's effort to reduce this nation's tremendous reliance on imported oil. Through tax incentives and direct grants, the government is, in effect, pay ing a homeowner approximately $1,000 to install a solar hot water system.

Here's how the savings work: A typical solar water heater costs about $2500 installed. If you act now, you can qualify for a $400 grant from HUD (U.S. Department of Housing and Urban Development) when you install an approved system. Then, next year when you file your federal income tax, you will be able to deduct an average of $620 from your tax. So, that typical $2500 installation actually costs only $1480.

Why buy solar now? There has never been a better time.

- The technology is tested and proven.
- Solar contractors have the experience to install your system properly.
- HUD-approved systems carry five-year warranties.
- HUD grants and tax incentives finally make solar hot water systems economically attractive.

Think of solar as an investment in your future. It's a hedge against inflation, foreign political crises and shortages of oil and natural gas. Solar is clean, non-polluting and limitless.

Note: Savings will vary depending on equipment, family size and hot water use patterns:

Act now! HUD grants expire Sept. 30, 1979

Learn more about solar, the HUD $400 grants and Federal, state and local tax incentives. Contact your state energy office at the address listed on the back.

Northern Energy Corporation
Northeast Solar Energy Center
70 MEMORIAL DRIVE • CAMBRIDGE, MA 02142

Figure 1. HUD Flyer

5. Speakers Bureau

To date, our trained personnel have completed over 50 speaking engagements specifically on SWH. In this endeavor, we have reached over 3,000 potential solar consumers.

NESEC has developed two slide presentations. The first is a short, 20-minute presentation utilized at service clubs and trade shows and designed to inform the public of the benefits of solar and the incentives available. The second presentation, of two hours' duration, is utilized at adult education seminars and community college lectures. It describes proper installation procedures and problem areas to avoid, in addition to subjects discussed in the shorter presentation.

At each engagement we emphasize the following:

- Region's dependence of foreign oil
- Installing SWH will allow the consumer some control over his energy future.
- SWH technology is available now
- Experienced solar contractors are in place now
- Installed costs and potential savings
- Incentives are available to reduce costs: federal, state and local
- Solar water heating can provide 40 to 60 percent of a consumer's hot water requirement in the Northeast

After each speaking engagement, particularly those to the Adult Education groups, we have seen a substantial increase of HUD applications returned to the State Energy Offices from the area where the speaking engagement was held.

6. Press Conferences

NESEC has held two press conferences announcing Operation Sunpower that have been supported by industry and federal and state governments. The first was held on March 16, 1979 at NESEC's Cambridge headquarters and resulted in 35 newspaper articles and coverage by six radio and television stations. The second press conference, to kick off Operation Sunpower in the Pennsylvania/New Jersey area, was held in Philadelphia on May 31. That conference resulted in 30 newspaper articles and was covered by 21 radio and television stations. In addition, both conferences were covered by United Press International and Associated Press and resulted in widespread coverage throughout the eastern seaboard.

7. Media Follow-up

We have systematically solicited media interviews on SWH with the following results. To date there have been 30 in-depth newspaper interviews, reaching a total circulation of 3.2 million; and 18 radio and television interviews reaching literally millions of additional consumers.

8. Marketing - Public Service Campaign

If solar energy is to be successful, it must be marketed like any other product. In fact, the successful manufacturers bear out that theory. As part of NESEC's efforts, we have worked closely with various state and industry representatives to develop ads for local media. These ads will be appearing in July, August and September in selected target areas.

We have worked with SEIA (Solar Energy Industries Association) and NASC (National Association of Solar Contractors) in this endeavor. At least four manufacturers will run additional advertisements concurrently in the target areas. Several contractors will also piggyback this effort.

In addition, we have begun work on Public Service Announcements (PSA) which we believe will heighten the awareness of solar energy in consumers residing in the Northeast. These PSA announcements will appear in newspapers and on radio and television throughout our region.

It is our strong opinion that industry must advertise repeatedly so that the consumer can be made aware of the benefits of solar energy. Also, we must not forget third party credibility. An industry representative can advertise, however, a third party that will substantiate solar benefits will assist in building up the consumers' confidence. The building of that confidence will accelerate solar sales while at the same time decrease the nation's dependence on foreign oil.

9. Other NESEC Outreach Efforts

Bill Stuffers

To date, at our request, eight utilities have sent bill stuffers to more than two million consumers in Pennsylvania, Massachusetts, Rhode Island and New Hampshire, alerting these homeowners to the HUD program. At least three other utilities will follow suit in July and August, reaching an additional one million consumers.

Target Mailings

85,000 selected homeowners have been sent information on the HUD initiative and federal tax credits. These people were selected by income, location and previous interest in solar water heating.

Assistance to Industry

Over 75 members of industry, either manufacturers, dealers or contractors, have been assisted since the inception of our Operation Sunpower campaign on March 16, 1979. The assistance has ranged from distributing to industry the names of 12,000 homeowners interested in SWH, to formulating marketing and financial programs for small solar companies.

Installation Workshops

As a sequel to last year's series of 35 installation training workshops (to over 1,800 attendees), three separate installation workshops have been held in the last two months at the Center for homeowners and/or contractors in Massachusetts. Over 150 people have attended these workshops which are designed to familiarize the attendees with installation problems to avoid and to educate them on correct methods of installing solar water heaters. Five other states have requested this program, and workshops will be held at ten different locations by September 30, 1979.

New England Fuel Institute

We have completed two solar workshops with the New England Fuel Institute (NEFI), designed to bring additional capable and qualified installers of solar water heaters into the field. To date, 60 different oil dealers have attended these seminars. Three additional workshops are scheduled through September, 1979. NEFI informs us that 40 of their 1,900 dealers are currently installing solar water heaters. Our mutual goal is to secure 60 additional dealers by the end of the fall. We hope to expand this program to New York, New Jersey and Pennsylvania.

Through our relationship with NEFI, we have been able to ascertain that the average oil burner in New England operates at a 50 percent efficiency. That efficiency takes into consideration combustion, flue, transmission and jacket losses. The finding is significant, as solar critics often point to a 70 to 80 percent efficiency for gas- or oil-fired water heaters. The 50 percent efficiency is even lower (approximately 40 percent) when considering tankless oil water heating systems. This will also allow us and the rest of the solar industry to refute various anti-solar articles which have appeared from time to time.

Utility Interface

We are currently working with three utilities: Northeast Utilities of Connecticut, Central Vermont Public Service Corporation and Public Service Electric and Gas of New Jersey. These corporations have asked us to assist them in their own solar water heating programs.

Surveys

In conjunction with the New York State Energy Office we are developing a survey which will be mailed to all New York applicants for the HUD $400 Initiative. This survey will gather data on attitudes towards solar water heating and consumer reasons for participating in or dropping out of the program. The data will be particularly valuable as it will reflect current attitudes in the post-Three Mile Island/gasoline crisis period.

We have completed mailing survey forms to participants in our adult education seminars, installation workshops and oil dealer seminars. The results of these surveys will allow us to determine what ratio of participants have actually installed SWH systems as well as how many contractors have entered the solar business.

We shall report on these results in late September, 1979.

Monitoring Performance

We have contracted to install a total of 200 monitoring systems throughout the region. To date we have installed 74 systems as shown in Table 5. An interim report on our findings will be published in November, 1979.

Table 5

Monitoring Systems Contracted/Installed

State	Total Systems	Systems Installed
Pennsylvania	50	29
New Jersey	35	0
Massachusetts	35	27
New York	20	0
Connecticut	20	0
Rhode Island	5	5
New Hampshire	5	4
Vermont	5	4
Delaware	5	5
Maryland	20	0
TOTAL	200	74

Outreach Activity to Date

Method		Audience Reached
Speakers Bureau		3,000
Target Mailings		85,000
Bank Stuffers		200,000
Trade/Home Shows		300,000
Utility Bill Stuffers		2,000,000
Media:	Press Conferences	8,000,000 (estimated)
	Newspaper in-depth interviews	3,200,000
	Radio/TV talk show interviews	3,000,000
TOTAL		16,788,000 (estimated)

RESULTS

Table 6 illustrates the status of the HUD Grant Program by state through June 30, 1979.

Table 6

HUD GRANT Installation Status: June 30, 1979

State	3/1/79	6/30/79	+Δ	Remaining Grants
PA	400	600	200	2,200
NJ	275	431	156	1,294
MA	190	425	235	950
NY	267	449	182	418
CT	150	237	87	513
RI	45	152	107	98
NH	15	84	69	116
VT	20	43	23	107
TOTAL	1,362	2,421	1,059	5,696

Since the beginning of NESEC's program, 1,059 SWH systems have been installed (44 percent of the total installations to date). This activity has been given sharp impetus by Operation Sunpower.

Table 7 illustrates that 1,840 grant applications have been approved out of 9,458 requested since we began our campaign.

Table 7

Summary of Grant Application Activity

State	Applications Sent to Consumers	Applications Approved	
	3/1 to 6/30	3/1 to 6/30	June only
PA	1,850	347	200
NJ	1,348	210	175
MA	1,566	250	137
NY	1,578	418	418
CT	1,660	400	90
RI	738	90	26
NH	475	70	29
VT	243	55	11
TOTAL	9,458	1,840	1,086

The most significant figure in this table is the 1,086 grant applications approved in June. This is a direct result of our outreach activity and it must be noted that none of these 1,086 approvals have been counted as "installed to date." Preliminary tabulations for July indicate an additional 1,000 applications have been approved.

We fully expect to move all HUD grants in our region by the end of the 1979 installation season.

CONCLUSIONS

Inflation, OPEC, and Three-Mile Island have contributed to the public's awareness and need for alternate energy sources. NESEC's campaign has educated the consumer on the benefits of solar water heating, and that knowledge is now being translated into sales. However, two barriers remain and must be eliminated if the number of solar installations is to continue to escalate. Those barriers are initial high cost and lack of sufficient qualified contractors to satisfy consumer demand.

High Cost

In two years, the installed cost of a SWH system has increased from $2,200 to $2,650. While the HUD grants and federal tax credits reduce that cost to approximately $1,600, the homeowner must still pay the total cost "up front." Only consumers in the upper income brackets can afford solar water heating at that cost. Yet, every homeowner having a site suitable for solar should be able to afford an installation.

Qualified Contractors

Due to experience gained in the New England Electric Experiment and the HUD Initiative, solar contractors have banded together in the Northeast. They have solved many installation problems that are only now surfacing in Florida and California. However, due to their small number, these contractors will not be able to keep up with the demand for SWH installations which has and will continue to increase.

Recommendations

1. Long-term, lower-cost loans, similar to those recommended by Senator Heinz on May 31, 1979 at the Operation Sunpower press conference in Philadelphia, must be made available to homeowners, thereby offsetting the initial cost of a SWH system. Additionally, it would be extremely beneficial to the industry if each state in the Northeast could follow Vermont's lead and initiate substantial state tax credits for solar energy equipment. That initiative would assist in lowering the region's dependence on foreign oil and build up our economy by reducing the balance of payments.

2. Fuel oil dealers and other heating specialists must be encouraged to enter the solar field. They should be reminded that they are in the "energy business". By entering the solar field they would increase overall sales of solar equipment as well as broaden their financial bases.

3. Finally, those manufacturers that are sincere in seeking a portion of the domestic solar water heating market must improve their marketing efforts. At the same time they must train their dealer/installers in proper sales and installation techniques. In short, a foundation of installer-dealer-manufacturer relationships must be laid and successfully built upon. The Northeast Solar Energy Center can and will play a significant role in this effort.

Executive East: A Solar Retrofit

Conrad D. Gohlinghorst

Executive East is a 2½ story office building located in Stamford, Connecticut. The building was constructed in 1969 and contains 25,000 square feet of office space. The original space heating and cooling system consisted of 70 water-to-air heat pumps connected in a closed cycle hydronic loop. Hot water was supplied to the heat pumps from a 2800 gallon storage tank maintained at 80°F by two 75 KVA boilers.

Executive East was retrofitted with a solar space heating system under a DOE Cycle 1 cost sharing contract. The solar system was completed in September of 1978 and officially dedicated and placed into operation by Mr. Jackson Gouraud, Deputy Under Secretary for Solar Commercialization (DOE), on September 29, 1978. The system operated beyond expectation throughout the entire heating season until May of this year when it was shut down for the summer.

Executive East is located at 41° latitude and its flat unobstructed roof, with the long axis pointed 5° west of south, made an excellent candidate for solar retrofit. The roof was equipped with an array of 138 single glazed, selectively coated copper, liquid flat plate collectors totaling 2561 square feet. These collectors are mounted at 55° to horizontal, in six rows, on a Corten weathering steel framing system. The steel mounting network is supported by the existing steel columns of the building. The construction of the mounting system which included penetration and recovering of the roof was one of the most difficult, time consuming and costly phases of the project.

The collectors are augmented by 2927 square feet of King Lux polished aluminum reflectors mounted at 10° to horizontal. The reflectors are eight feet in length and have a reflectivity in excess of eighty per cent. The reflectors are designed to increase the incident energy by an average of 30 % over the total heating season reaching a maximum of 46% in February at the height of the heating season.

The reflectors are hinged enabling them to be folded up over the collectors during the cooling season when no fluid is circulating The closed reflectors protect the collectors from overheating when not in use and also protect the reflective surfaces from the elements during the summer. Clips are provided to secure the reflectors in either the open or closed position to prevent wind or storm damage.

The collectors are connected by a reverse return copper piping configuration with a Teflon hose reinforced bronze wire braid flexible connector and flow regulating valves after each group of four collectors. The flexible connectors provide well in excess of the expected maximum one half inch expansion experienced by the four collector array. Adjustment of the flow regulating valves in tandem with the measurement of temperature drop across the collector plate provides uniformity of flow and temperature distribution across the array.

All exposed piping in the system is insulated with 1½ inches of urethane coated with Zeston vinyl coating. All insulation joints are wrapped and sealed with a waterproof sealant. This insulation system results in minimum heat loss from water/ethylene glycol fluid in the collector loop.

The heated fluid from the collector loop is pumped through a two section shell and tube heat exchanger heating the water in a 6000 gallon storage tank. The 6000 gallon tank is insulated with 4 inches of foamed urethane coated with a water proof cover and partially buried in a fenced area behind the building. Water at the top of the tank shows a temperature drop of less than $1^{o}F$ in a 16 hour overnight period with no circulation.

There are four basic modes of system operation. The first mode is one in which solar energy is available for collection at a time when the building space has no demand for heat. In this mode, the water/ethylene glycol solution circulates through the collector loop, absorbs the available heat, and then passes through the heat exchanger and transfers the heat into the 6000 gallon water storage tank.

The second mode of operation occurs when there is a demand for space heating and hot water is available in solar storage. The 70 heat pumps in the closed cycle hydronic loop will draw hot water from in the 6000 gallon solar storage tank until the temperature of the tank falls below $80^{o}F$ or there is no longer a space heating demand.

The conventional or back up heating system will operate only after the hot water in solar storage has been depleted and the building space continues to call for heat. In this third mode the heat pumps will draw the hot water from the back up 2800 gallon conventional storage tank which has been heated by the two 75 KVA boilers during off peak hours. Only when both the 6000 gallon solar storage and 2800 gallon conventional storage are depleted will the system operate directly off the electric boilers and use peak power for heating.

The fourth and final mode is the cooling mode. The majority use of the mode comes in June, July and August when the collectors are not in operation and the reflectors are locked in the folded vertical position. The cooling system is the original conventional system and does not utilize any of the solar production in its operation. The collectors do provide some shading of the roof which reduces the cooling load on the building.

The Executive East solar system is fully instrumented and is being monitored by the Department of Energy under the National Solar Data Program. The system is equipped with conventional and shadow bar pyronometers for measuring both direct and diffuse radiation available for collection. Along with the pyronometers are 40 other sensing points which are constantly monitored by the National Solar Data Program Center. Included in the sensing points are 23 temperature sensors which include inside and outside ambient air, three points in the solar tank, nine points in the building supply and return lines, four points in heat exchanger/collection loop, two collector inlet and two collector outlet points, as well as a collector surface temperature sensor. The balance of the data gathering points consists of eleven electric power monitoring points and six flow sensors. The information gathered by the instruments is sent back to the National Solar Data Program. The performance results will be the subject of discussion at another session of this conference. A local three channel digital readout device provides instant information from any of the 42 sensor points. The local performance monitoring provides the building owner with valuable information which enables the system to be maintained in top working order and to minimize down time or use of the back up system operating at peak electrical load. The only problem in the total first heating season operation was the failure of one temperature sensor which resulted in the three way valve remaining in the open position. The building owner noticed the malfunction almost immediately on the local digital readout. The portion of the system involved was shut down, the sensor was replaced and in a short time was back in operation.

Although the official performance data will be monitored and recorded by the National Solar Data Center, the building owner has kept accurate monthly and cumulative KWH consumption figures for the 77-78 and the 78-79 heating season. A total of 516,000 KWH were used during the 78-79 heating season compared to 619,680 for the 77-78 season resulting in a 103,680 KWH savings. The average electrical KWH rate in Stamford for Executive East was 4.13 cents providing a total monetary savings of $4300.00.

The system was designed to handle 50 percent of the heating load and provided in excess of that during the 78-79 heating season. The almost trouble-free operation of the system has been the outstanding feature of this solar retrofit system in its first season of operation. This is in a large part due to the building owners interest and close supervision of the system from the beginning of construction through start up and continuing through operation of the first heating season. The Lutz-Sotire Partnership is to be congratulated for their work and dedication to the project. Other project participants to be recognized are Sanford O. Hess and Associates, Consulting Mechanical Engineers, Wormser Scientific Corporation, Designers, the Copper Development Association Inc. who put all of the participants together and of course DOE for providing funds and technical assistance.

Town of Concord, Massachusetts
Solar Space Heating Project at the Municipal Light Plant Building

David W. Hartwell

Introduction

The historic Town of Concord, Massachusetts acknowledges its role in the U.S. Department of Energy's National Solar Heating and Cooling Demonstration Program with enthusiasm.

The intent of this presentation is to supplement the detailed project description reports, performance reports, and cost reports published by DOE which are available at this Regional Conference. These reports include descriptions of the site and building, the solar system, performance evaluation instrumentation and techniques, and performance assessment. These definitive and comprehensive reports are an essential part of this presentation.

The Town of Concord's solar project is a space heating system which uses air as the heat transfer fluid. It has been retrofitted to our municipal light building, a one-story masonry block structure with a flat roof which faces 14 degrees east of south. The building provides space for combined garage, warehouse, and administrative functions.

The first priority of the solar system is to heat 5,700 square feet of garage/warehouse area. Excess solar energy is used to heat the 2,700 square foot administrative area. The Concord Light solar system is a National Science Foundation initiated project. Final design was completed, approved, and funded in late fall, 1977. Construction started in November and was completed in March, 1978.

Design Philosophy

The air system was selected to determine the efficiency of air as a heat transfer medium in a large volume (113,400 cubic feet), multi-zoned space heating application in the New England climatic area. IBM monthly performance data document that the system has consistently performed well. The preliminary design was developed by Intertechnology Corporation of Warrenton, Virginia, under contract with ERDA with the assistance of our solar consultant, Dr. Richard Thornton of M.I.T. Final design and contract documents were developed by the architectural-engineering team of Earl R. Flansburgh and Associates, Inc. and BR + A Consulting Engineers, Inc. of Boston. Massachusetts. The solar system was installed by Worcester Air Conditioning Company, Inc., of Ashland, Massachusetts.

The solar system was initially designed to supply heat to the 5,700 square feet garage area only and was sized accordingly. We concluded that, to achieve maximum performance and efficiency in the marginal heating months, it was logical to extend the main heating supply duct to the administrative area. The design requirements were to maintain a temperature of 50 degrees F in the garage area and 68 degrees F in the administrative area. The collector array is 1,932 gross square feet. The ninety two 3' x 7' panels are single glazed, selectively coated, and roof mounted on three rows of plywood enclosed steel frames.

The fully insulated, 1,210 cubic foot rock storage bin is located inside the building on the concrete floor adjacent to the air handling unit. The bin is sized to hold 2.7×10^6 BTU's based on one cubic foot of rock storage holding 2,300 BTU's. The design flow rate of 3 cfm/ft^2 of collector is based on the collector manufacturer's recommendations. An additional 8-10% efficiency might have been achieved by increasing the flow rate to 6 cfm/ft^2 of collector. This would have required doubling the capacity of the air handling equipment and ductwork and would not have been cost effective.

Space limitations below the roof dictated that we locate the collector ductwork above the roof. This ductwork is internally insulated and protectively enclosed to insure minimum heat loss. Roof penetrations are confined to three locations to minimize the potential for leakage. The project is designed for a system air flow of 5,250 cfm. All ductwork is insulated, taped, and sealed, to minimize air leakage.

The collectors are ducted 8 panels to a series with ductless side-to-side gasketed connections sealed with silicone. Each series has one inlet and one outlet duct. The inlet and outlet collectors are connected to the collector supply and return ducts with transition boots and connector ducts. Each series has manually operated balancing dampers.

A flat plate collector was selected because of its applicability to a low temperature system. The collectors were roof mounted because a ground mount would have produced shading problems due to the ground level proximity of an adjacent building. The entire building was retrofitted with two inches of fire-rated sprayed cellulose insulation and the overhead doors were weatherstripped to prevent excessive outside air infiltration. Additional, detailed, design information is available in the Department of Energy's Solar Project Description Report for the Concord Municipal Light Building.

Construction

Construction started in November, 1977 and was completed in March, 1978. Although weather conditions during the winter of 1977-78 were severe, construction was completed on schedule with no major problems and no cost over-runs.

Problems Encountered and Solutions

After startup in March, the system was extensively pressure tested to determine the extent of air leakage. Test results proved conclusively that system air leakage was excessive which was totally unacceptable. The contractor's test results were confirmed by the on-site data monitoring system. Additional testing indicated that most of the leakage was occurring through the collectors. We had anticipated a minimal system leakage factor but nothing of this magnitude. The collector manufacturer, after on-site inspection, agreed that each of the 92 panels would be replaced at no cost to the Town or DOE.

A test series of 8 replacement collectors was shipped and installed in August. We developed a procedure for pressure testing and smoke bomb testing which documented that the collectors still leaked excessively. We determined that the main areas of leakage were in the manufacturer's inlet/outlet (rear exit) connections and also the collector-to-collector gasket connection. The manufacturer modified the inlet/outlet connection at the factory; we retested the modified panels and determined that leakage at the rear exits had been reduced to an acceptable percentage. The balance of the inlet/outlet connections were modified at the factory prior to shipment but it was mid-September before a substantial partial shipment of the new collectors was delivered on-site.

Another series of 8 replacement collectors was installed and tested. Additional leakage was found at the collector-to-collector connections and at the rear of the collector enclosure itself. At this point in time, all concerned parties concurred that the contractor would field repair any potential source of leakage through the collectors. Most of the field repair, or rework, was accomplished by sealing the applicable collector areas with a combination of silicone, duct sealer, and "hardcast" tape. Preliminary observations indicate that the leakage factor has been reduced from approximately 60% to a range of 3-5%.

- ### Instrumentation

The project is fully instrumented. Evaluation data is included in the Department of Energy's National Solar Data Network Program. The cooperation of the IBM site analyst has been invaluable. Three operational problems were resolved as a result of this cooperation. The first problem was caused by a leaking damper in the collector inlet duct. Significant thermal losses through the collector array were occurring when the system was operating in the Heat from Storage mode. We resolved the problem by adding a new damper in the collector return duct. System performance improved.

In December, IBM advised that one of the small electrical auxiliary unit heaters was continuously drawing approximately 620 watts. The problem was traced to a defective thermostat which was replaced. In February, as a result of on-site observations and close coordination with the IBM site analyst, we discovered that the potentiometer setting in the logic control unit which controls the operation of the Heat from Storage mode had inadvertently been set too high with the result that storage heat was being utilized at less than maximum efficiency. We adjusted the setting and significantly improved system performance.

The importance of minimal leakage in an air system should be emphasized. Ductwork should be tightly sealed and insulated. Dampers should provide positive seal. Although we had specified damper D4 as critical and had upgraded it prior to installation of D4-A, we are advised by the IBM site analyst that the new D4-A "slams shut".

Maintenance

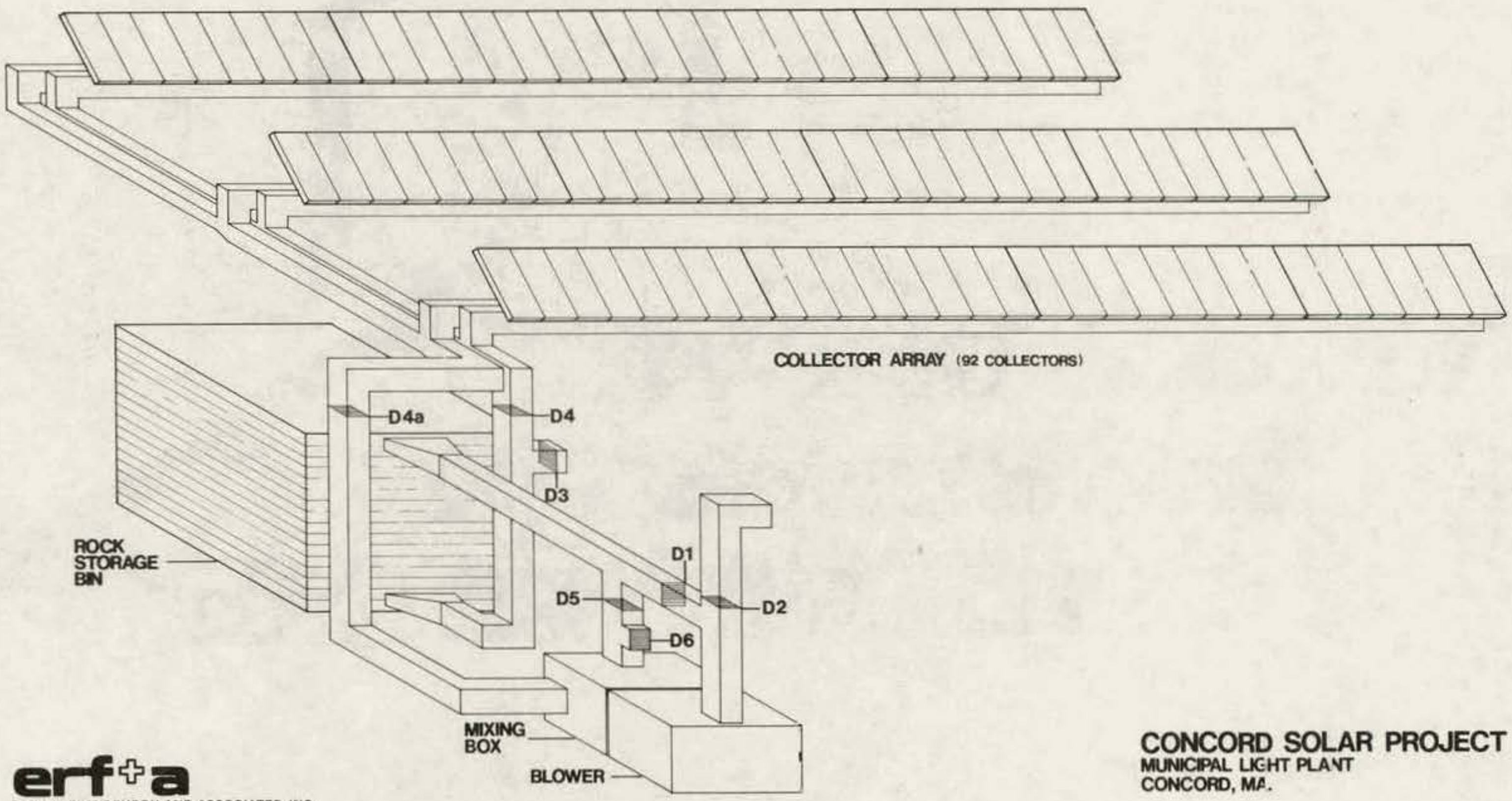
System maintenance is minimal because of the system's relative simplicity. The major components include 92 air collectors, a rock storage bin, an air handling unit, motorized control dampers, a logic control unit, and a duct distribution system. Maintenance procedures include: lubricate and adjust air handling unit, replace filters, inspect control system, and inspect ductwork. To date, maintenance has been minimal.

Summary

Concord's solar project was selected by the U.S. Department of Energy to demonstrate the feasibility of using air as a heat transfer medium in a large-volume, multi-zoned space heating application in the New England climate. We believe we have successfully demonstrated the heating application and plan to convert the system to demonstrate the feasibility of a nocturnal cooling application.

The close working relationship and enthusiasm that developed early in the project, and the cooperation of the Department of Energy and its support groups has been invaluable.

Thank you.



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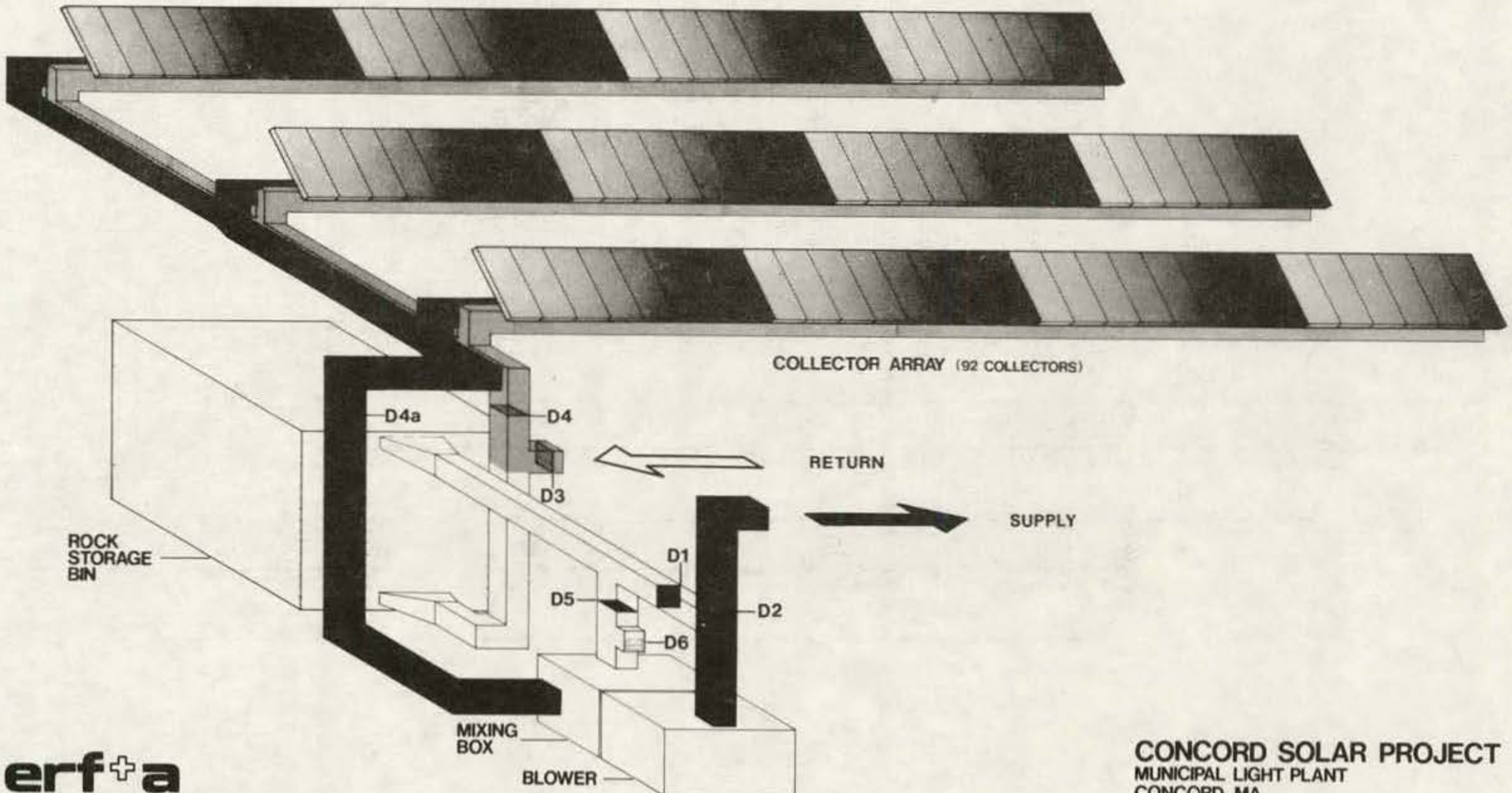
EARL R. FLANSBURGH AND ASSOCIATES, INC.

CONCORD SOLAR PROJECT
MUNICIPAL LIGHT PLANT
CONCORD, MA.

SEQUENCE NO.1
SPACE HEATING FROM COLLECTORS



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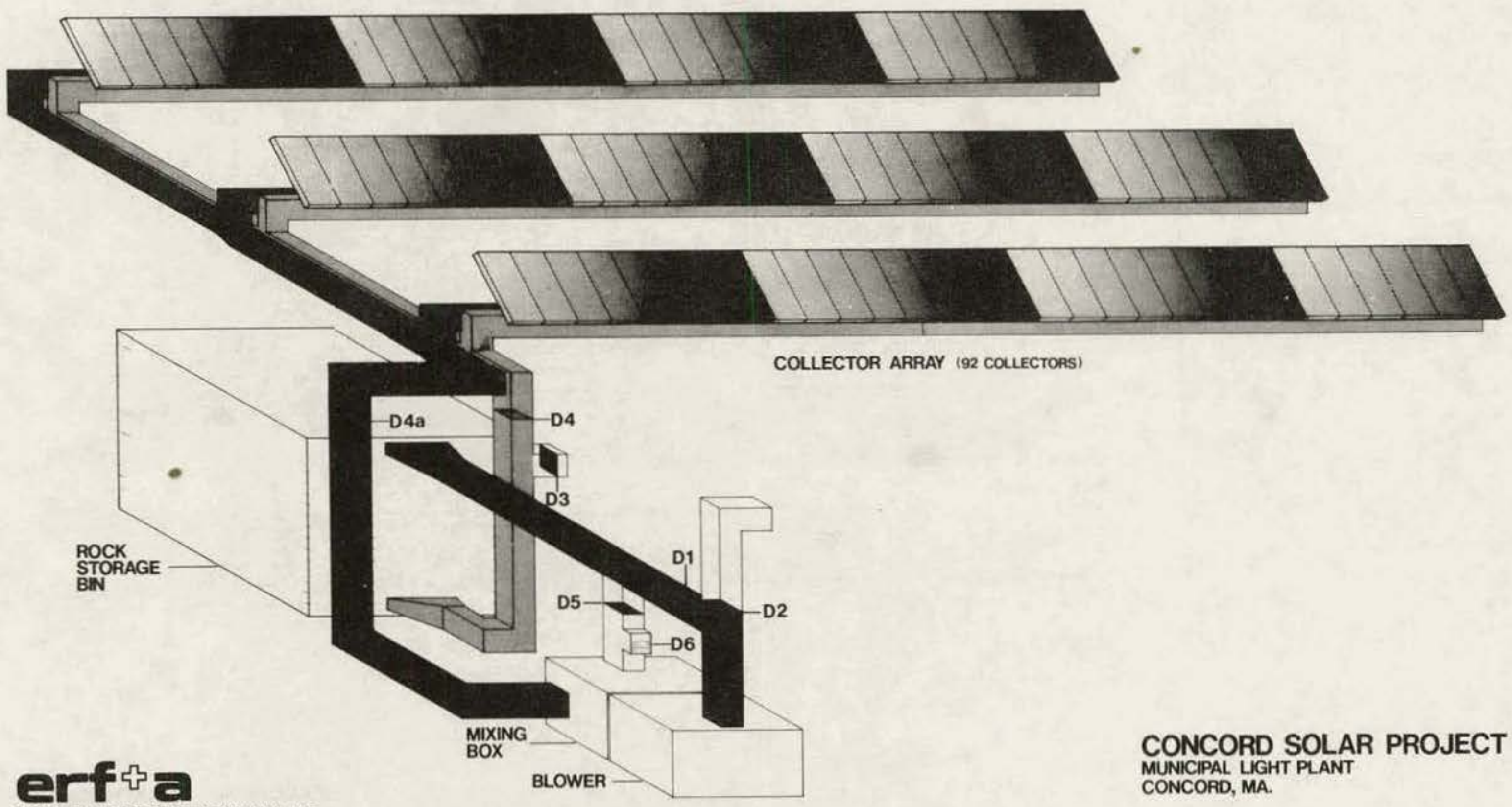
EARL R. FLANSBURGH AND ASSOCIATES, INC.

CONCORD SOLAR PROJECT
MUNICIPAL LIGHT PLANT
CONCORD, MA.

SEQUENCE NO. 2
STORING HEAT FROM COLLECTORS



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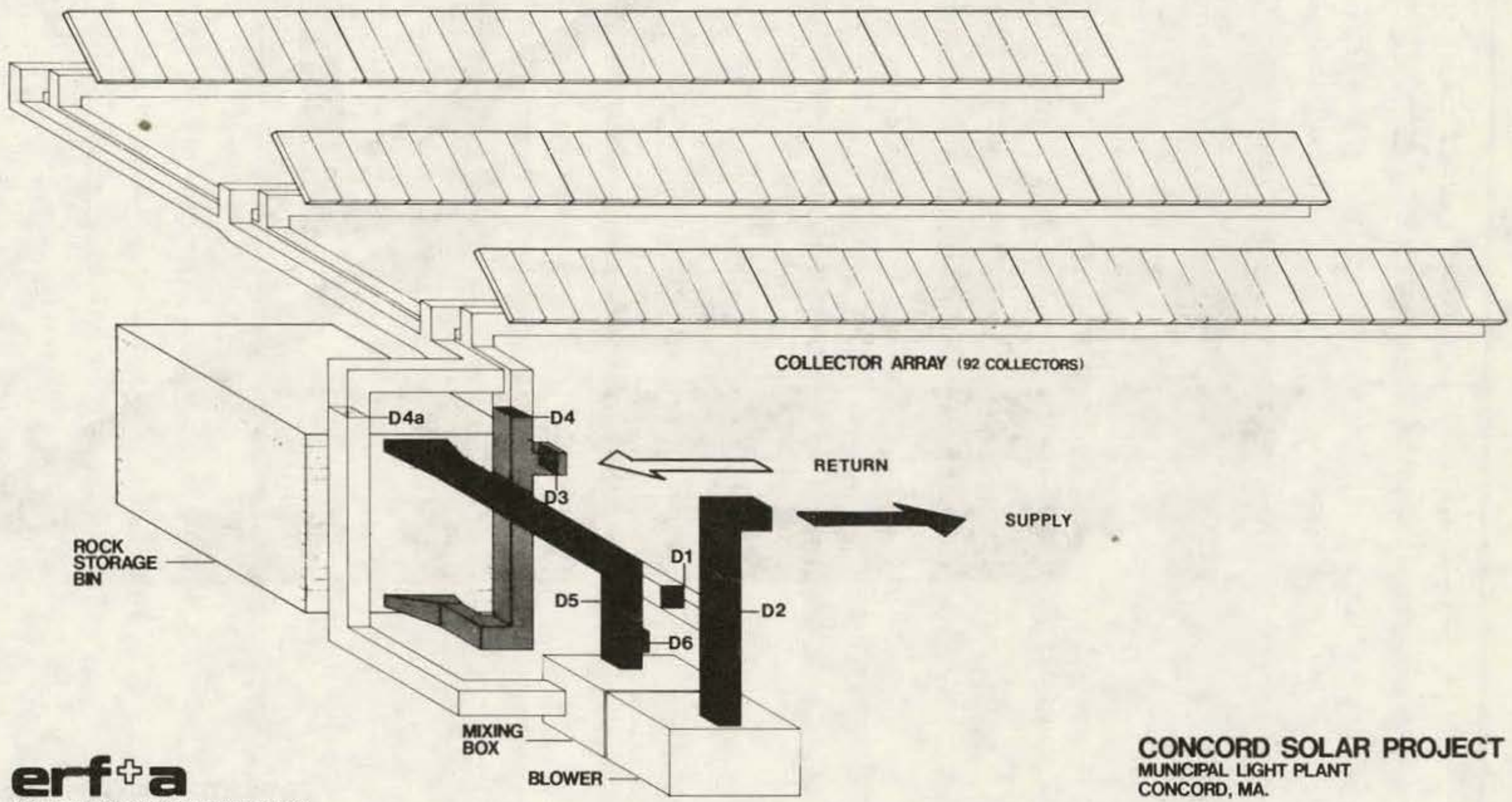
CONCORD SOLAR PROJECT
MUNICIPAL LIGHT PLANT
CONCORD, MA.

SEQUENCE NO. 3
SPACE HEATING FROM STORAGE



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EARL R. FLANSBURGH AND ASSOCIATES, INC.

CONCORD SOLAR PROJECT
MUNICIPAL LIGHT PLANT
CONCORD, MA.

Experiences and Cost Analysis Gained During Design and Construction of the Contemporary Systems, Inc. Solar Center in Walpole, N.H.

Presented at the U. S. Department of Energy Solar
Update Conference, July 31, 1979, Philadelphia, Pennsylvania

Presented by John C. Christopher, President
Contemporary Systems, Inc.

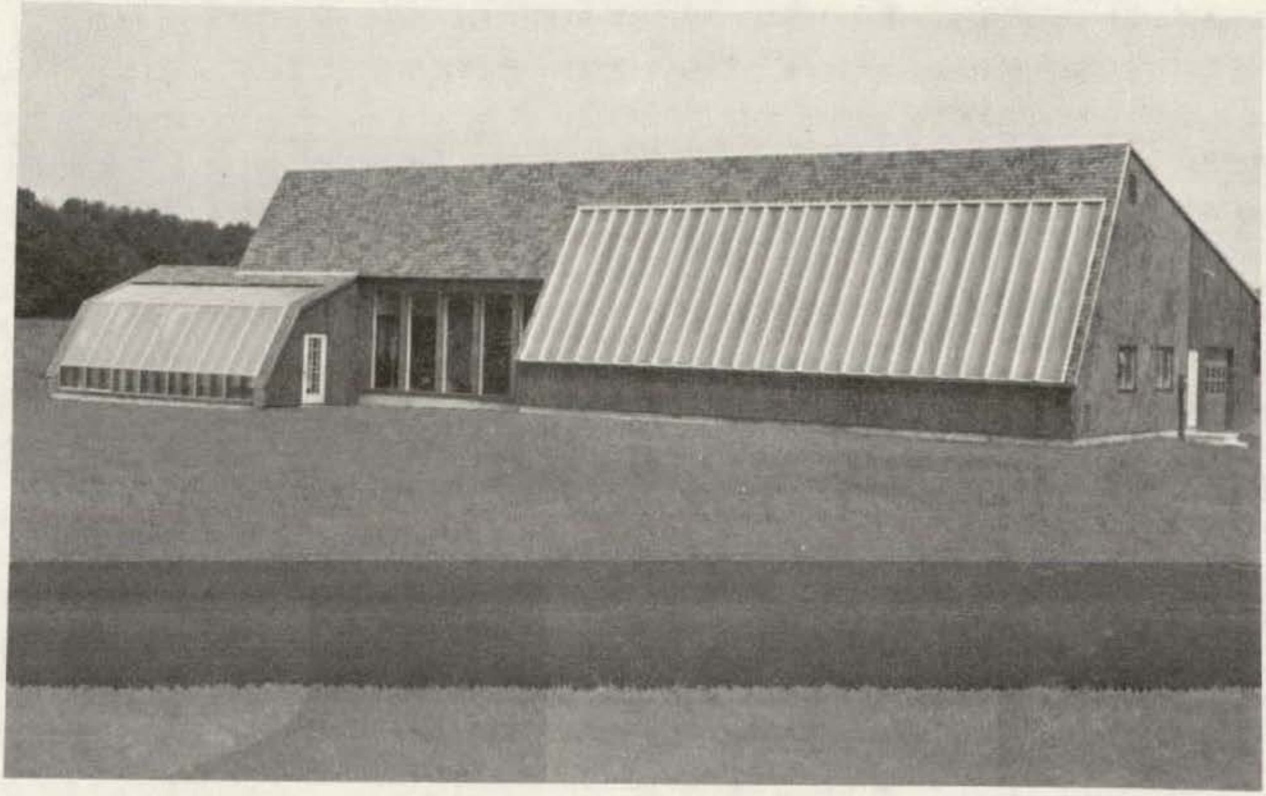
The Contemporary Systems, Inc. (CSI) Solar Energy Center serves as the corporate headquarters, design development and manufacturing facility for CSI. The project was funded partially by a grant from the Department of Energy under the second round of commercial solar demonstration projects. The building is an 83% solar sufficient structure located in a 7,600° day climatic zone. The solar energy system provides space heating through three (3) independent solar energy systems. An 800 sq. ft. active, air-type, collection system supports the base heating load of the structure. This is supplemented by 190 sq. ft. of direct passive gain window area located in the production and office areas. In addition, a 360 sq. ft. attached, hybrid sun-space provides added heating and storage capacity for the office area. The total system is attractively and functionally integrated into the building structure.

During the course of the construction of this building, considerable practical experience has been gained relating to the direct interface with the building trades. We were fortunate that we had a totally cooperative general contractor, who did his utmost to accommodate the needs and installation requirements of the solar energy system. It must be noted that during the design and installation process the system must be configured in such a way that it conforms to convention building practices and standard scheduling procedures. It is undesirable and unwise to expect the general contractor to perform tasks that are new or unfamiliar to him. For this reason, the CSI system has been configured in such a way that conventional tradesmen and sub-contractors are capable of installing the components with a minimum amount of instruction. We feel that this fact greatly reduced the overall cost of the active solar energy system. The active system was composed of 25 CSI Series V Air Collectors, each 16 ft. in length and two ft. wide. The gross area of this array is 800 sq. ft. The total cost for the active system installation was $20,448. When credits for the roofing system are subtracted, this brings the net effective cost to $18,688 or an installed cost of $23.36/sq. ft. The following table is a detailed analysis of the active system. We feel that an installed system cost in the range of $23/sq. ft. provides a very cost effective investment for the potential commercial user. It should be noted that the CSI system was a prototype in many respects and we feel that substantial further price reductions can be obtained through additional refinements in the system's configuration.

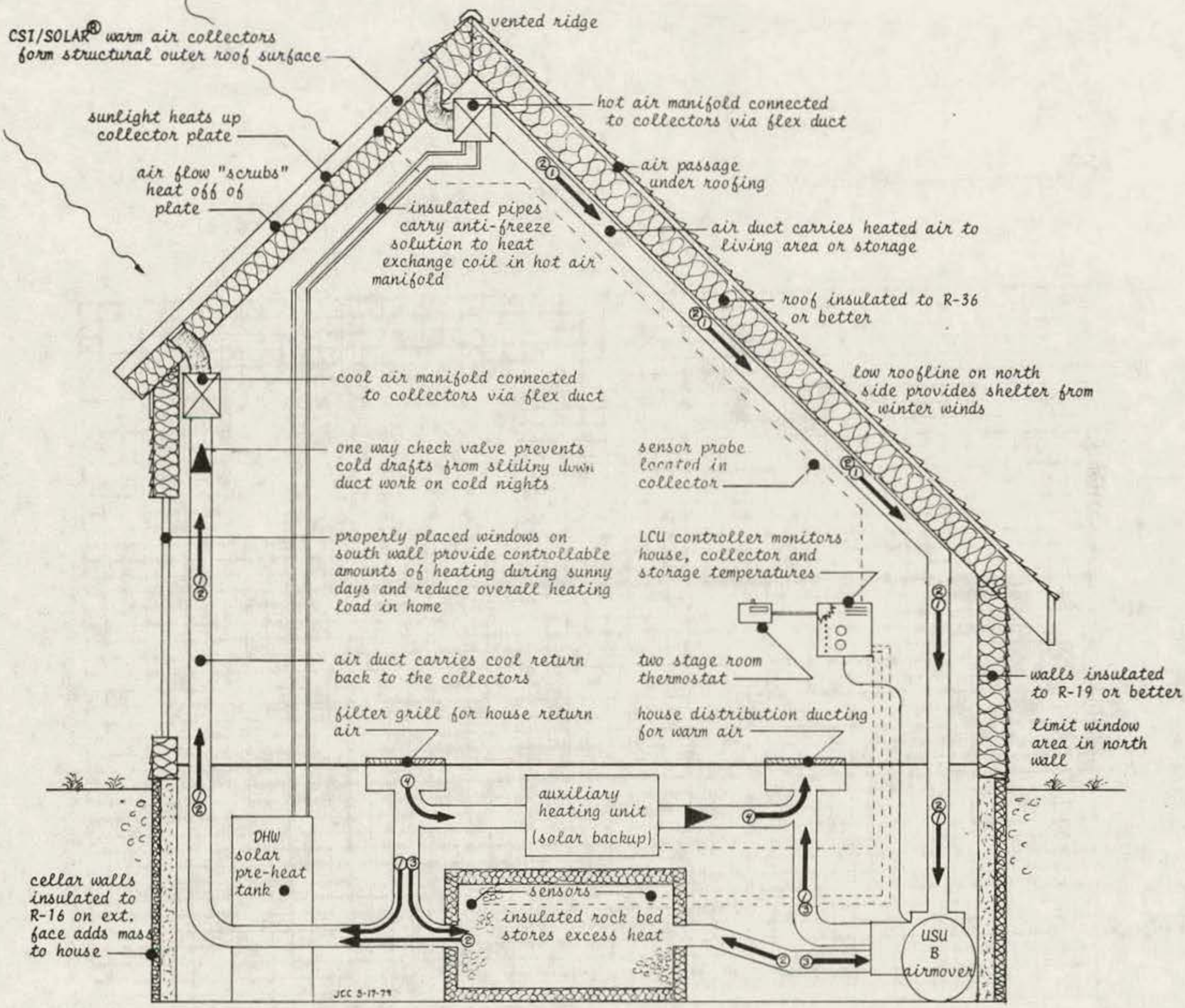
As a source of comparison, CSI is currently doing system installation work in the residential market sector. These systems, ranging in size from 350 sq. ft. to 450 sq. ft. of collector area which provide both space heating and domestic hot water for the residence are averaging from $14/sq. ft. to $18/sq. ft. of installed system cost. It should be noted however, in this case that to achieve these low-cost figures the roofing credit allowance has been taken as well as the Federal Income Tax credit. With an effective installed cost ranging from between $14/sq. ft. to $18/sq. ft. of system cost the economic viability of including a solar energy system in new building construction is unquestionable. This is especially true in the New England region. Current prices for #2 fuel oil are ranging from 68¢/gallon to 78¢/gallon and anticipated prices for the coming winter exceed $1/gallon in many instances. With these considerations and the inevitable fact that fuel oil prices will escalte beyond these prices, it is our conclusion that solar energy systems are not only economically viable, but an economic necessity in all new building construction.

Relative to the passive elements in this solar demonstration project, we have found that they too represent a very suitable vehicle for reducing overall heating loads in new building construction. I would like to caution however, that excessive use of passive gain can be more harmful than beneficial in that overheating can occur within the passive gain area. One solution that we found to this problem is the use of hybrid passive gain whereby the excess heat can be mechanically transferred or stored when necessary. Relative to cost of passive systems, we found them not to be quite as inexpensive as most people would claim. Direct gain window systems can cost in the range of $10/sq. ft. to $12/sq. ft. and while this is far cheaper than an active solar system, it provides no elements of control. It is our feeling, however, that a thoughtful integration of passive elements in any solar design is essential and that the mix of active, passive and hybrid technologies well integrated into a functional system will provide the best overall cost effectiveness in any project.

At this point we are awaiting our first winter of operation and look forward to monitoring the performance and reporting on the results.



Schematic Diagram of CSI/SOLAR® Warm Air System with DHW



FLOW PATH	MODE OF OPERATION	DESCRIPTION
no. 1	heat from collectors	heat collected is distributed directly into living area
no. 2	storage of heat	heat collected is stored in insulated rock bed
no. 3	heating from storage	stored heat is distributed to living area
no. 4	heating from auxiliary	after depletion of all available solar heat or if solar system can't keep up with demand auxiliary system will supply added heating

INSTANTANEOUS EFFICIENCY CURVE FOR THE CSI/SOLAR® SERIES V WARM AIR COLLECTOR.

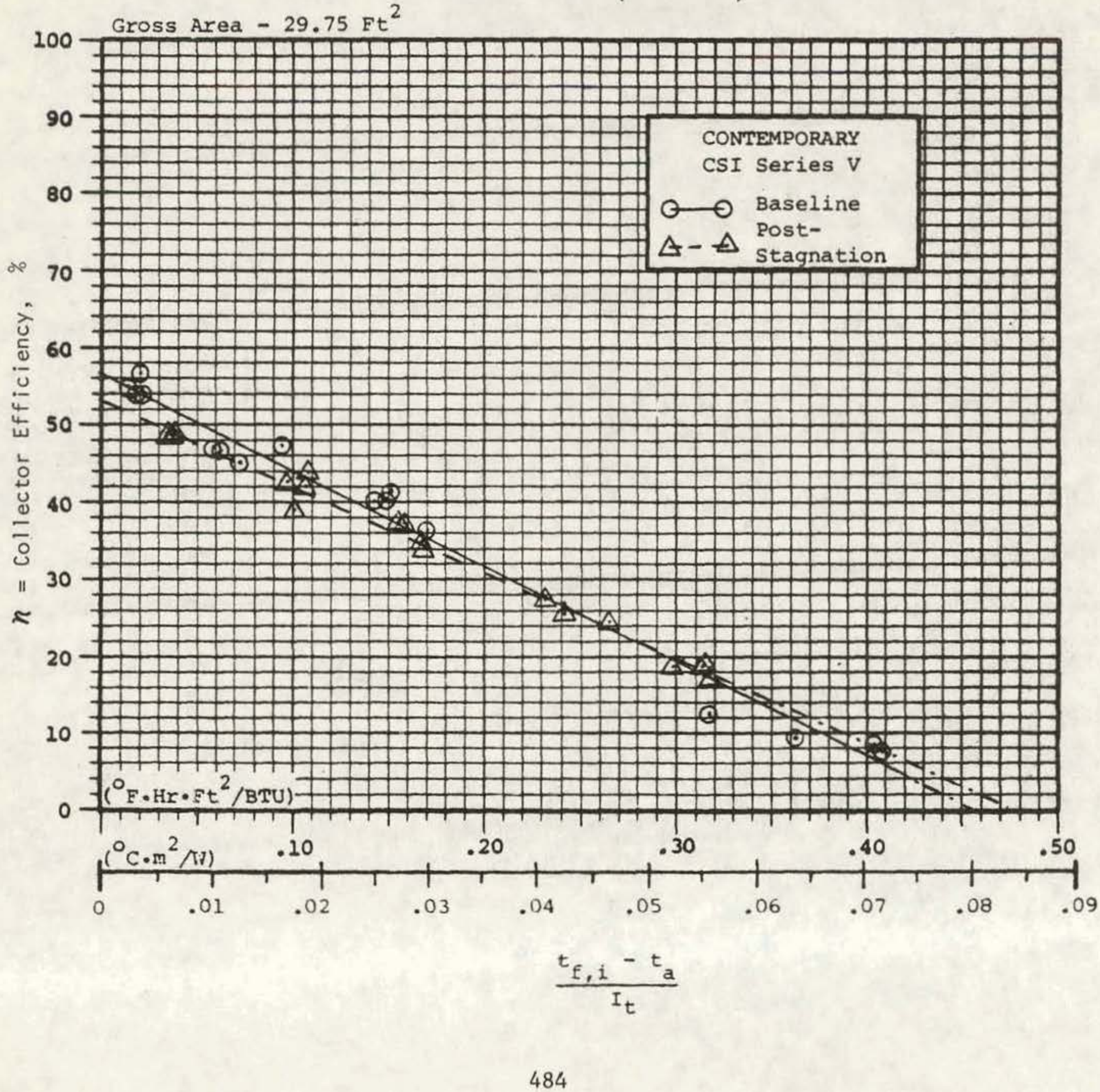
The solar collector thermal efficiency was determined using the methods provided in ASHRAE 93-77. The instantaneous efficiency equations are:

Thermal Performance Baseline Test:

$$\eta = 0.566 - 1.239 \left(\frac{t_{in} - t_{amb}}{I}\right) \quad \text{(1st Order)}$$

Post Stagnation Thermal Performance Test:

$$\eta = 0.533 - 1.112 \left(\frac{t_{in} - t_{amb}}{I}\right) \quad \text{(1st Order)}$$



ACTIVE SYSTEM COST BREAKDOWN SUMMARY

Collector and support structure	$ 1,190
Collectors and installation	10,700
Ducting and installation	2,250
Mechanical equipment	928
Storage and fabrication	3,080
Controls	850
Miscellaneous costs	1,450
Total:	$20,448
Roofing Credits:	- 1,760
Net Effective Costs:	$18,688
Cost/Ft^2 System:	$23.36/$Ft^2$

Estimate of Cost of Solar Collection System (Heating Only)

As Installed on CSI/Solar Center, Walpole, NH

1. Collector Support Structure

A) Materials: South wall of building is used for collector mounting. 2x12's spaced 24" on centers. Estimated Additional Cost	$ 930.00
B) Labor:	260.00
	$ 1,190.00

2. Collectors

A) Materials: 800 sq. ft. collectors	$ 7,880.00
Batten Caps	450.00
Flashing and miscellaneous	200.00
B) Delivery:	N/C
C) Mounting on Support Structure @ $.45/sq. ft.	360.00
D) Collectors connecting to manifold (labor and materials)	1,810.00
	$10,700.00

3. Ducting System

A) Collector Distribution System:	
Material:	840.00
Labor:	200.00
	$ 2,250.00

4. Insulation (costs included in ductboard ducting cost)

Estimate of Cost of Solar Collection System (Heating Only)

5. Heating & Cooling Equipment

A) Material (two air movers)	$ 928.00
	$ 928.00

6. Storage

A) Material: (bin, stone, manifolds)	$ 1,420.00
B) Delivery: included in material cost	
C) Installation:	340.00
D) Insulation:	1,320.00
	$ 3,080.00

7. Controls

A) Material:	$ 680.00
B) Labor:	170.00
	$ 850.00

8. General Construction

A) Roofing	$ 120.00
B) Equipment Room	700.00
C) Architectural	360.00
D) Excavation	270.00
	$ 1,450.00
TOTAL COST	$20,448.00

Credits toward system costs - roofing allowance	$ 1,760.00
Net Effective System Cost	$18,688.00
System Cost/Ft^2	$23.36/Ft^2
Total Building Cost	$99,940.00
Total Construction Cost	$170,800.00

Passive Solar Heated Warehouse

by

Bruce M. Keller, Arthur V. Sedrick

Kalwall Corporation
Manchester, New Hampshire

ABSTRACT

A direct gain passive solar system designed for low initial and life-cycle costs has been retrofitted to a 10,000 ft.^{2} warehouse section in Manchester, New Hampshire. A key element of the design is the use of 1750 ft.^{2} of Kalwall Corporation's Sunwall^r Solar Window as the south wall collector aperture. Sunwall^r is a specially developed sandwich panel with 77% solar energy transmission and an insulating "U-factor" of 0.41 BTUH/ft.^{2}-oF. The warehouse concrete slab and inventories provide thermal storage. Measurements of building energy needs and temperatures have been monitored by DOE/NASA/IBM. This passive system has operated successfully for two heating seasons supplying 55% of the warehouse section's heating needs, resulting in a seven year pay-back of installation costs at current fuel prices.

INTRODUCTION

There are literally millions of square feet of warehouse-type buildings in the United States alone today. These warehouses represent a substantial portion of national energy use for space heating purposes. Warehouses are excellent applications for passive solar heating systems. Warehouse buildings have large wall areas, one of which has to be facing in a southerly direction. Their inventories generally permit wide temperature fluctuations with no adverse effects. The combination of a concrete floor slab and the inventory can provide inherent absorbing surfaces and the thermal mass required to store excess heat during the day for release at night. Auxiliary lighting can be eliminated during the daytime hours providing additional energy savings from a passive solar system.

DESIGN PHILOSOPHY

The basis of the design philosophy for this project was to conceive a very economical and simple retrofit package to conserve energy in the millions of square feet of warehouse-type buildings throughout the United States that could live with the relatively wide temperature fluctuations.

The Kalwall Corporation has long been involved in the design, manufacture and installation of insulated, light transmitting sandwich panels for the walls and roofs of buildings and the design of a solar window wall panel, a key element in any passive design, fit Kalwall's expertise. Kalwall undertook a direct gain passive project because of the prospect of low initial and life cycle costs for a direct gain system and the virtual non-existence of information on the operational and maintenance costs of this type of system.

SITE SELECTION

Kalwall chose one of its existing warehouse/manufacturing structures in Manchester, New Hampshire as the site. The solar system was actually sized after business considerations dictated the size and area of the building that could be reasonably isolated for the project. One fourth of the existing 40,000 $ft.^2$ 1½ story building was partitioned off for the project, giving a floor area 75 ft. wide by 125 ft. long on the E-W axis. The west and north walls are insulated partitions to isolate it from the rest of the warehouse. The east wall is composed of standard Kalwall building panels which have a U-Value of .40 $BTUH/ft^2$ and light transmission of 40%. There is large freight loading door on the east wall which serves as the main entrance. Besides having the loading door for ventilation, the building was already provided with roof overhang to provide shading to alleviate possible overheating from the solar system during the summer months. Early design calculations of the site showed that basic energy conservation procedures were necessary and that a method of coupling the air temperatures in the warehouse to the thermal mass storage would be required for efficient heat transfer. Table I summarizes the specifications of the warehouse.

ENERGY CONSERVATION PROCEDURES

The existing 20 year old structure is of heavy timber post and beam construction with lightly insulating building panels on the walls and roof. The building lies on an 8 in. thick concrete slab raised approximately 3 ft. from grade. Heat loss calculations determined that edge losses at the slabs needed to be reduced drastically. Two inches of urethane foam were laminated around the perimeter foundation wall and covered with fiberglass sheeting for protection. Infiltration from the large 24 ft. x 16 ft. overhead loading dock door on the east wall was virtually eliminated by applying conventional weatherstripping techniques and by laminating two inches of urethane foam to the door panels themselves. No extra insulation was originally planned for the roof, but due to the severe winter of 1976-1977 the roof was retro-fitted in the Fall of 1977 with two inches of sprayed-in-place urethane foam on the top surface to insulate it and make it weather tight. Upgrading the roof insulation to a U-Value of .07 alone reduced building energy consumption from the original 800 MBTU/yr. to 500 MBTU/hr.

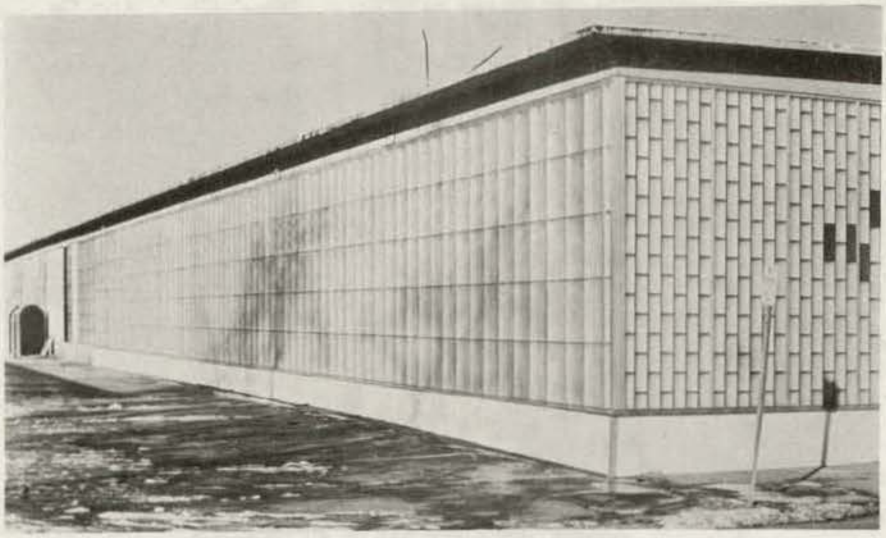
DIRECT GAIN SOLAR SYSTEM

The solar window system for the south wall was designed to be equal to, or more desirable than glass or plastic materials in cost, weight, impact resistance, solar energy transmission, resistance to degradation from ultraviolet radiation, U-value insulation and longevity. These goals were accomplished resulting in Kalwall's Sunwall[r] Solar Window Panel. Sunwall is a true "sandwich" panel 2-3/4 in. thick with fiberglass reinforced face sheets bonded to an aluminum grid core. The panel weighs 1.2 lbs./ $ft.^2$ and provides a solar energy transmission of 77% and an insulation U-factor of .41 BTUH/ $ft.^2$-^{o}F at two-thirds the cost of alternative materials

The Sunwall Solar Window system was retrofitted in place of the existing entire due south facing 14 ft. by 125 ft. wall, amounting to 1750 $ft.^2$ of gross collector aperture. (Figure 1)

Table 1 - Solar Warehouse Specifications

1. Location: Manchester, New Hampshire
2. Latitude: 43^{o}N
3. Heating Degree Days: 6500 (January - 1250 DD)
4. Average Temperature: 32^{o}F (winter), 75^{o}F (Summer)
5. Warehouse Dimensions: 125 ft. x 75 ft. x 14 ft.
6. Floor area: 10,000 $ft.^2$
7. Collector area: 1,750 $ft.^2$
8. Storage: Concrete Slab and Inventories
9. Solar Energy Supplied: 270 x 10^6 BTU/yr.
10. Owner/Builder: Kalwall Corporation
11. Collector Manufacturer: Kalwall Corporation
12. Solar System Contractor/Designer: Kalwall Corp.



SOLAR HEATED WAREHOUSE DEMONSTRATING EFFECTIVENESS OF PASSIVE SOLAR HEATING.

Fig. 1 Kalwall Solar Heated Warehouse

This allows solar radiation to be admitted directly into the warehouse space where it comes in contact with the black painted slab and the stacks of inventory. The 8 in. thick concrete slab is exposed for 3.5 ft. between the Sunwall and the first row of inventory. This strip of slab was covered with a black paint having an absorptivity of .95 and an emissivity of .95. The effect of this direct gain system configuration is that it stores energy as heat energy in this first row of inventory and the exposed band of concrete creating a warm area adjacent to the wall. A method of improving the heat transfer between this immediate area and the rest of the warehouse was addressed next. Based on small scale tests, five 24 in. diameter fans, each rated at 5500 cfm (with 1/4 HP motors) were installed along the south wall, four feet below the ceiling and 3 feet from the Sunwall[r], with their air flows directly toward the north wall. Each fan is controlled by two low-cost thermostats. One thermostat is located near the roof directly over the fan and the other is located 5 ft. above the floor below the fan. The thermostats are set to turn the fans on when the warehouse temperature drops below 55°F or rises above 85°F. Inventories in the warehouse were set on conventional pallets, running in east-west rows. The pallets were oriented to allow free air circulation along the slab under the pallets, so air could circulate from the south wall, along the roof, down the north wall, along the floor and back up the Sunwall.

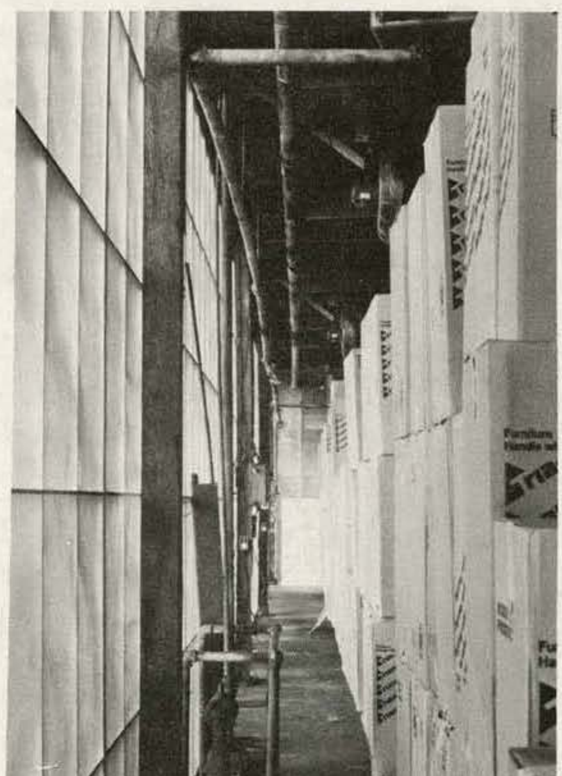


Fig. 2 Interior View of warehouse showing Sunwall[r] Solar Window, Heat absorbing slab, and inventories.

When the air temperature at ceiling height reaches 85°F, or warmer, the fans distribute the heat throughout the warehouse to be absorbed by the thermal mass storage. When the air temperature near the floor drops below 55°F, the air circulation draws heat from the thermal mass storage to help maintain the minimum temperature of 45°F.

In addition, two hot water fan heaters provide auxiliary heat during periods of prolonged cloudiness or at night. One unit having a nominal 196,000 BTUH rating with a 1/3 HP, 3740 cfm fan is located near the south wall. The second unit with a nominal rating of 209,000 BTUH and a ½ HP, 4885 cfm fan is located above the loading dock.

The circulation fan sizes, quantity and resulting flow rates were based on preliminary tests and calculations. The resulting system works rather well with an average air velocity of between 20 to 50 feet per minute throughout the warehouse.

MAINTENANCE

No major maintenance has been required to keep the system operational, due to the inherent simplicity of passive systems. In fact, virtually no maintenance of any sort has been performed.

CONCLUSION

This direct gain solar system has met the design goals of low initial costs and low operating costs. The cost of retrofitting the south wall with the Sunwall[r] Solar Window system was approximately $8,000. The system is supplying 55% of the heating requirements of the solar heated warehouse space for an estimated savings of 270 million BTU/yr. With a current fuel oil price of $.70/gal., this results in a yearly savings of $1,900 or four years to payback the initial investment at today's fuel prices.

Other passive design considerations which contributed to the successful operation of this system include:

1. Applying basic conservation measures to minimize building heat losses due to infiltration and conduction, by adding weather-stripping, perimeter insulation and adequate roof and door insulation.

2. Leaving an exposed and blackened slab area adjacent to the south wall. (Black polyethylene plastic draped over inventories next to the wall will also augment performance by decreasing reflection).

3. Supplying adequate air flow for heat transfer between the heat storage mass (slab plus inventories) with circulation fans, north-south aisleways and clearance between the slab and inventories.

4. Providing roof overhang to prevent chances of summertime overheating.

In addition, allowing the warehouse temperature to have the widest permittable temperature swings will also increase the contribution of the direct gain system in meeting building energy requirements.

Very large scale applications of the Sunwall^{r} system in new warehouse construction are also being undertaken. An example of this is a 120,000 ft.^{2} warehouse (figures 5 and 6) located in Plover, Wisconsin, and owned by Warehouse Specialists, Inc. which was completed in October 1977. This passive warehouse uses a 600 ft. long by 24 ft. high Sunwall^{r} window system. The warehouse was designed to have 95% of its heating requirements supplied by passive solar heat. Performance data indicates that this design goal has been achieved. Minimum interior design temperature for the building is 40^{o}F.

Under construction

Collecting sun's energy

SUMMARY

Construction and performance monitoring of a direct gain passive warehouse has demonstrated the cost-effectiveness and ease of operation of passive solar heating. The Sunwall^{r} Solar Window System has supplied 55% of the warehouse heating requirements, resulting in a 7 year payback at current fuel prices. The direct gain approach to solar energy utilization with its low initial cost, low life-cycle costs, and inherent reliable operation provides the consumer with a means to save energy and dollars today.

INVITED PAPERS
LOS ANGELES, CALIFORNIA

WESTERN SUN AND THE SOLAR TRANSITION

Donald W. Aitken, Ph.D.
Executive Director
Western Solar Utilization Network

In the interest of using federal funds for effective support of solar commercialization activities at the regional, state and local levels, the network of Regional Solar Energy Centers was established by the U.S. Department of Energy in 1978. The Western center, entitled the Western Solar Utilization Network (with the attractive acronym Western SUN), headquartered in Portland, Oregon, was given the responsibility for the region encompassing thirteen of the western states, containing about 18% of the U.S. population in 49% of the U.S. land mass.*

To guarantee that Western SUN's mission is directly responsive to the states it is to serve, the agency was founded as an instrumentality of the thirteen states, with the thirteen governors, each acting through an appointed representative, serving as the Board of Directors. And to assure an organization that would be directly accessible to local businesses, builders, financial institutions, governments, school districts, professional and grass roots groups and individuals, Western SUN has been organized on a largely decentralized model, acting for the major part of its program through a network of fourteen State Solar Offices (one in each of twelve states, and two in California). Through this network, Western SUN relies on an outreach services approach of workshops, education, technical assistance, information transfer, marketing strategies and business assistance.

Neither Western SUN, nor any federal agency (or, in the case of the Regional Solar Energy Centers, federally contracted centers) will actually be able to <u>do</u> the transition to a renewable energy resource base. That will be accomplished by people, although with helpful support, information and stimulus from governmental efforts. Accomplishing the transition from a dependence on non-renewables to a reliance on renewables means generating sufficient momentum so that the transition will actually occur. A large dose of both governmental and engineering humility will serve this effort well, as we seek those useful, clever, elegantly simple and appropriately-designed solar applications that are now emerging in abundance, and help extrapolate the best of these to widespread application (giving credit where credit is due), even as we turn our research directions toward future improvements and discoveries.

In this view, it is seen that Western SUN's long-range objective is to go out of business, at such a time that further significant governmental intervention in the transition to an energy economy based primarily on renewable sources of energy is no longer useful. Since Western SUN is staffed largely by people formerly active in direct service to energy conservation and renewable energy resource applications, this remains our personal, as well as organizational, objective. But until that satisfying moment, it is clear that Western SUN has a major mission, one that will involve a careful integration with all other governmental and organizational efforts, and that must rely on the trust and support of those persons whom it is to serve.

*Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.

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The Suncatcher House
by
James Plumb

Living Systems has been designing and building passive solar homes using a variety of passive systems for the last five years. One of these systems, "the Suncatcher", has been incorporated in 12 recent solar homes. The two houses discussed in this paper are the Tarkington Suncatcher, a HUD cycle III demonstration project in Davis, California, and the Sacramento Suncatcher, a demonstration passive tour house built for the Pacific Gas and Electric Company.

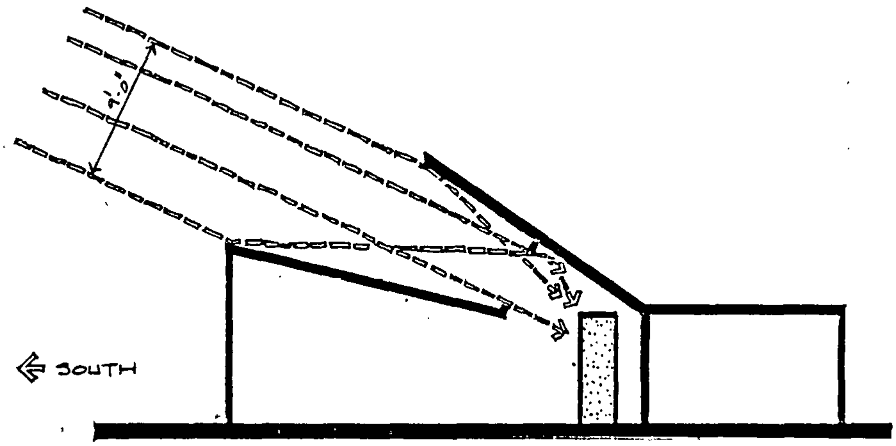
Suncatcher houses use the reflective roof and soffit configuration illustrated in Figure I on the following page. Winter sunlight entering the clerestory windows is concentrated and directed onto large metal culvert pipe used as thermal storage elements. These pipes are placed deep in the living space, rather than behind ground level south windows, leaving these windows open for views and natural light. In summer, unwanted sunlight is blocked by the deep overhang of the Suncatcher. Manually operated, insulated shutters are used on the interior to reduce winter night heat loss and heat gain in summer.

The Tarkington house is one of the first Suncatcher houses. According to performance data furnished by IBM who is monitoring the house for the Department of Energy, the Tarkington house achieves 75% of its heating and 100% of its cooling from its passive system. This house was built by a general contractor who, although he had no previous experience with solar, encountered no significant problems. The solar system, including the culvert pipe and the insulated shutters were subcontracted by Living Systems. The house was finished on budget and sold on the open market.

The Sacramento Suncatcher, which has been open to the public for nearly a year as a P.G. & E. tour house, was constructed in the same way. Living Systems installed the solar components and a general contractor built the house itself. This house has also performed impressively. Figure II shows the house's performance on a summer day when local utility companies broke all previous records for power consumption, primarily because of heavy air conditioning use. Without mechanical air conditioning, the Sacramento Suncatcher maintained on this day interior temperatures between 80-82° F, despite an outdoor peak of 109° F. The day in question was the last day of a five day period with temperatures registering over 100° F. During this period, more than usual numbers of people toured the Suncatcher house, including over 350 on one day.

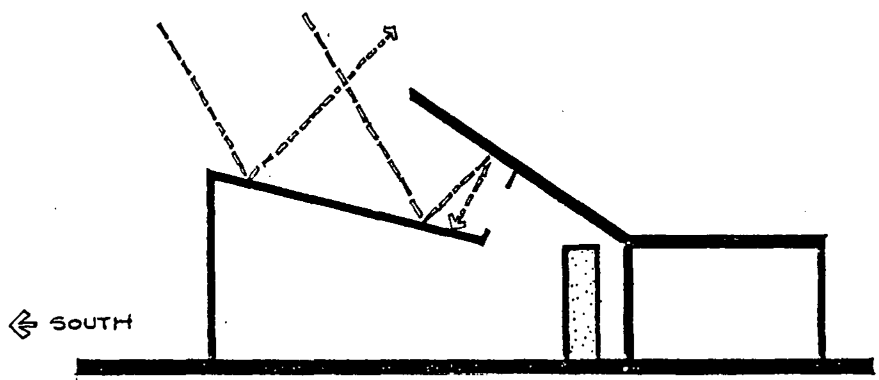
The house's ability to provide cooling, even under such extreme conditions, makes its passive system an obviously attractive and viable alternative for reducing peak energy demands. Preliminary data on winter performance is equally impressive and comparable to that of the Tarkington house.

The performance of Suncatcher houses makes the Suncatcher system an exciting and promising new passive design. The Suncatcher's advantages include:



DECEMBER 21, 12:00 · 26° SUN ANGLE

WINTER RADIANT GAINS CAN BE INCREASED 50% THROUGH THE "SUNCATCHER" SCOOP BY THE USE OF REFLECTIVE SURFACES ON THE ROOF BELOW AND THE EAVE ABOVE THE WINDOW. THE WINDOW IS SHUTTERED TO PREVENT NIGHT HEAT LOSS.



AUGUST 21, 12:00 · 62° SUN ANGLE

SUMMER HEAT GAINS ARE MINIMIZED. THE OVERHANG SHADES THE WINDOW FROM DIRECT SOLAR RADIATION, AND THE GEOMETRY OF THE "SUNCATCHER" PREVENTS SUNLIGHT REFLECTED OFF OF THE ROOF FROM ENTERING THE WINDOWS. IN ADDITION, THE WINDOW IS SHUTTERED TO REDUCE CONDUCTED HEAT GAIN.

SUNCATCHER PERFORMANCE

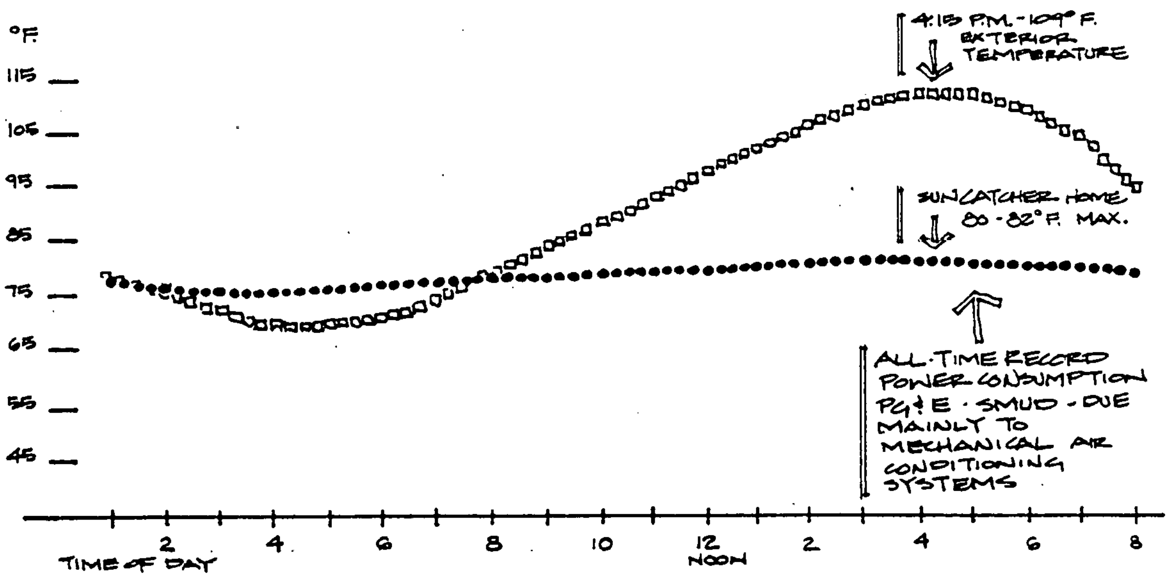
SUMMER AND WINTER

Figure I

* design flexibility which allows flexible placement of thermal storage elements deep within living spaces

* extensive natural day lighting which reduces energy consumption generated by artificial lighting as well as creating high, dramatically lit interior living spaces

* the creation of a distinctive "solar architecture" which announces in the house's dramatic and distinctive roofline the building's sun catching function



SUNCATCHER SUMMER PERFORMANCE

Figure II

In these first houses, however, there were also problems encountered that are instructive for anyone building a passive home. To begin with, the Suncatcher roof configuration also catches rain more easily than conventional roofs, and unless care is taken with the Suncatcher cone's construction and flashing, leaks can occur. In areas of heavy annual snowfall (24" or more) snow buildup rules out using the Suncatcher. The unusual shape of Suncatcher houses also increases framing costs, but not beyond averages for typical, non-solar custom designed houses. Similarly, the need to use more than one type of roofing material can add to labor costs because of specialization within the building trades. Suncatcher windows with tilted back glass must be tempered and of skylight quality. Ordinary aluminum sliding windows are cheaper and can be used in a vertical position.

A problem encountered with the aluminum roofing used as a reflector is that it can become tarnished if not stored out of the rain before actual installation. It has also proven difficult to find many roofing subcontractors with extensive experience in installing metal roofs.

For these reasons, Suncatcher designs are not ideally suited for production-type tract housing, although they do not cost more than other passive solar houses or conventional custom-designed homes.

Public response to some Suncatcher passive system elements has been varied. The Pacific Gas and Electric Company's survey of visitor attitudes indicates some dissatisfaction with the exposed concrete slab floor and the large culvert pipe water storage cylinders. Most visitors, however, find the house surprisingly comfortable, and many express disbelief when told that heating and cooling are provided naturally by the Suncatcher's passive system.

It is the impressive thermal performance of this house that will be, we feel, the real basis of its appeal and we are confident that passive solar houses will capture an increasingly larger share of the housing market.

RESIDENTIAL STRUCTURES IN THE COLORADO ROCKIES

BY

RONALD SHORE

-Abstract-

This paper will present 3 residential projects which were funded in part by the H.U.D. cycle of Demonstration Solar grants. The projects:

1. "Dawn" A single family residential structure
2. "Rifle One" A multi-family project for an energy resource impacted area.
3. "Sun-up" An experimental dormitory for a private Secondary School.

represent a diverse group of residential structures which have unique social, energy, architectural and economic program requirements.

Introduction:

The following three projects in the cold mountain climate of the Colorado Rockies portray the results of a continuing collaborative effort between Architects and Solar Consultants in achieving an integrated approach to responsible architectural solutions. In addition these projects, along with others, represent some considerable effort in standardizing passive approaches to accomodate the use of common readily available building materials and their incorporation into conventional building construction.

Perspective

I. "Dawn" - Single Family Speculative Residence.

A number of solar homes are being built in the Roaring Fork Valley of Colorado. A majority of these solar structures are large, expensive custom homes. There was a need for an affordable, speculative solar home for until the public sees affordable solar homes on the market, the prevailing view that solar technology is too expensive will continue.

The primary program for this project was therefore defined - Design and build an affordable solar home to compete in the single home subdivision market of the Roaring Fork Valley.

This project was extremely successful, both technically and economically.

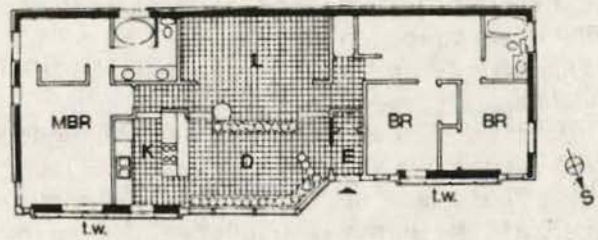


Fig. 14. Floor Plan, MBR master bedroom, K kitchen, D dining, L living, E entry, BR bedroom, T.W. Trombe wall.

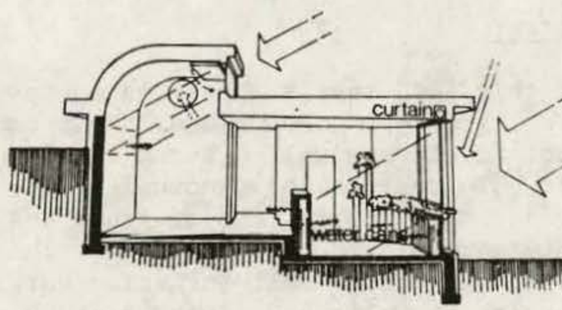


Fig. 15. Section at Living and Dining.

Energy Conserving Features

A.

1. Walls (R-Value, Type of Construction): Generally below grade R = 20 Masonry construction - insulated exterior.
2. Ceiling or Roof (R-Value, Type of Construction): frame construction, R = 42
3. Windows and Doors (U-Value, Type): U = .69 Double glazed insulated units; Marvin wood operables. One door - wood solid core U = .49
4. Appliances and Equipment: Low energy use appliances (Amana refrig. and range) fluorescent lights bathroom and kitchen
5. Airlock Vestibules: Yes X No_____
6. Other: Beam daylighting; natural cooling; below grade construction; Jotel Combi to provide wood heat option; movable insulation, open plan

B.

a. Earth Berming: yes - north, east and west exposures
b. Entrance location(s) with regard to winter wind: winter winds from NW - entrance on south
c. Natural ventilation: operable windows and high ceiling vents
d. Natural light: yes - beam daylighting throughout
e. Natural vegetation:
   (1) Shading: There are no trees or high scrub oak on site
   (2) Wind breaks: No natural windbreaks - below ground construction
f. Orientation: Building is oriented with long axis east-west 15° west of south
g. Other: Impressive 180° mountain peak view to south - gentle south facing hill

Passive Solar Energy System:

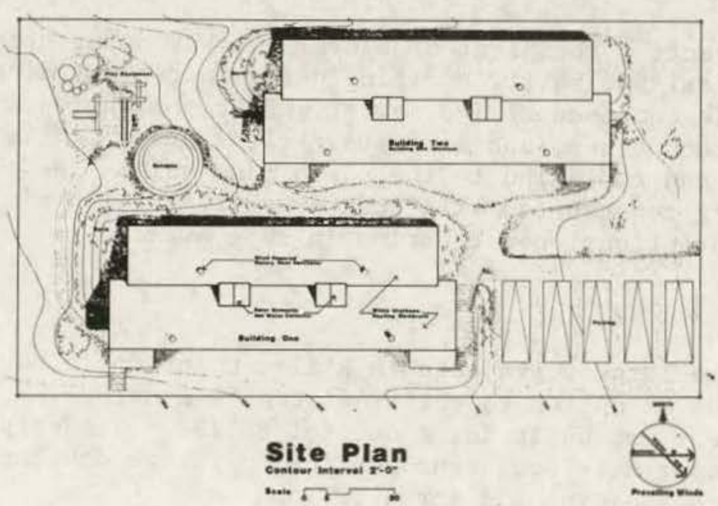
The solar system of this 1400 sq. ft. house is composed of Trombe walls and south facing direct gains glass. Bedrooms and kitchen are heated by 230 sq. ft. Trombe wall. Three vision windows occur in the Trombe walls. To capture the panoramic mountain views, the dining and living areas share 165 sq. ft. of south and southeast facing glass. Water containers provide 380 gallons of thermal mass, in addition to tile floors. Automatic self-inflating curtains provide night insulation for Trombe walls and dining glazing. Roof monitors provide clerestory light and direct gains to north rooms and mass walls.

Final Note:

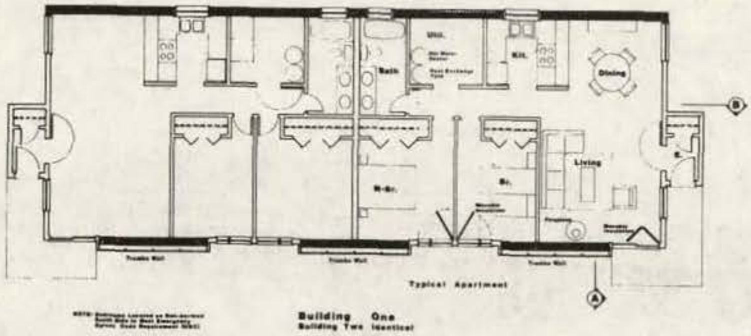
The building was built for $35/SF and was sold three days after the foundation was poured. This structure is the least expensive speculation building sold to date in King's Row Subdivision.

II. Rifle One - Duplexes; Rifle, Colorado.

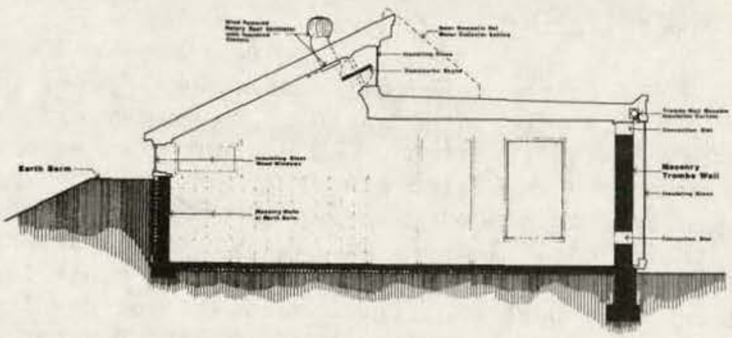
The need in Rifle Colorado (an oil shale impact area) for a demonstration of a fully integrated approach to energy efficiency design at realistic costs is obvious. At present this area is the fastest growing community in Colorado and with accelerated growth there is usually a void in planning and a motto of "Development at any cost." The traditional elements of high growth impact areas are present and this project has been a significant addition to the town of Rifle in showing both the city government and developers that yes! rental housing can be built which is indeed responsible from an energy, architectural and development point of view.



Site Plan
Contour Interval 2'-0"



Floor Plan



Section 'A'

Solar System:

This project, a recipient of a Cycle 4A HUD solar grant, consists of four identical 900 sq.ft. dwelling units in two buildings. The solar system is composed of 140 sq. ft. of Trombe wall per dwelling, direct gain south glass, and clerestory glass bringing light to north spaces and radiation to the north mass wall. These rental units are being constructed at a cost competitive with similar housing of conventional construction in this area.

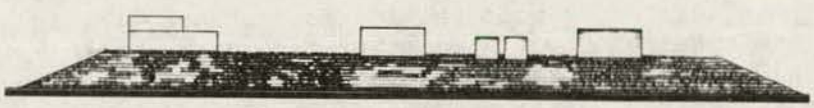
Final Note:

One of the largest projects in Rifle, Colorado is housing. This project offers an option to the trailer park syndrome.

The project was built for a cost of $31/SF. The city planner and the developer have now begun working on future development of this type on the adjoining 3 acres of land.

III. Sun-Up - An Experimental Dormitory for the Colorado Rocky Mountain School.

SOUTH ELEVATION



NORTH ELEVATION

Sun-up is a 5,500 square foot dormitory for fourteen students and one faculty family. With the exception of a second floor bedroom/study in the faculty residence, the building will be one level sunk underground and covered with sod. Only the southern wall will be exposed. Seven rooms for students (two students per room) open onto an east-west hallway interrupted in the center of the building by a living room. The faculty apartment is at the east end of the building and shares a storage and workshop area that separates it from the students' area. The workshop and storage area provides space needed by both students and faculty but also acts as a sound barrier and thus gives a measure of accoustical privacy to the family in residence.

Each student room has south facing windows and a water column-solar collector. During winter days, an insulated screen will be raised to allow the heat uptake by the collector. In the evening the screen will be lowered to minimize heat loss to the outside while doors behind the collectors will be opened to radiate heat out to the room. Each student, therefore, must act on behalf of his or her own comfort and any negligence on the part of one will not effect the comfort of others in the dorm.

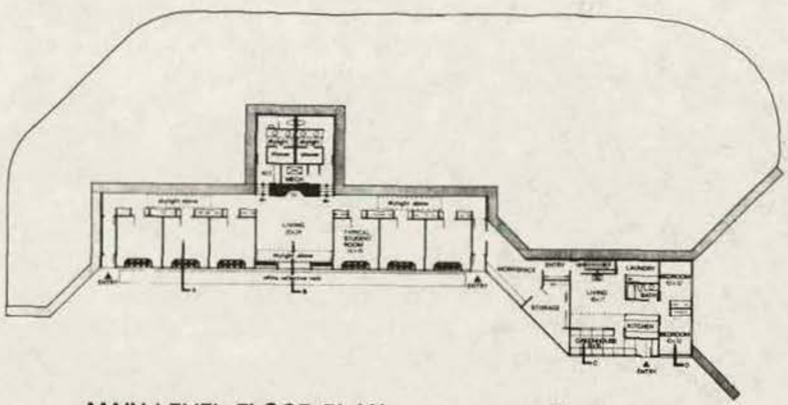
The building itself is heavily insulated (above Ashrae 90-75 standards) below the floor, in the walls, and in the ceiling. Earth moved up against the north, east, and west walls and on the roof further isolate the building from external variations in temperature. The underground design is thus an integral part of the thermal plan. It is also important for achieving harmony with the surrounding fields. Although burying the building increases construction cost, the extra cost will be returned by the seventh or eighth year through significantly lowered maintenance costs.

Colorado is one of the more suitable locations in which to employ a solar heating system. The number of clear days in the Carbondale area and typical winter temperatures are such that we can expect the solar system to provide more than 80% of the building's heating requirements. A wood burning furnace with hot air ducts to the extremities of the building will be used to supplement the solar system during prolonged periods of cloudiness or low temperatures. On the educational side, monitoring the temperature, cutting wood, and lighting and stoking the furnace are an easy way to remind ourselves what it takes to be comfortable.

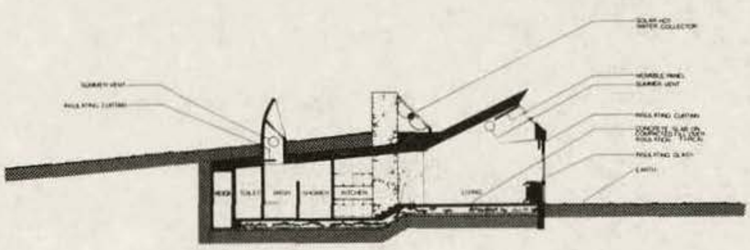
Economically conservative assumptions suggest that operation alone of a conventional gas heating system would cost approximately $75,000 over a 20 year period (repair and maintenance not included). The operation of the solar system costs nothing (again repair and maintenance not included) even though the installation cost of the solar system is $22,000 more than a conventional system, the economic advantages remain apparent. In fact, the housing cost per student per year in a conventional dormitory at CRMS is $1,224. In Sun-Up, we'll be able to house students for $638/yr.

Because Sun-Up is an attempt to provide a comprehensive awareness of our impact on the environment it is also designed to minimize the waste of water and the heat that is usually associated with it. Water from sinks and showers will therefore be held in a reservoir under the floor so that its residual heat can can be utilized. That same water will also be used to flush toilets. Any excess water will be carried by pipes to subfloor storage in a greenhouse that fronts the faculty apartment. From here it will be used to water plants. Traces of soap, we are told, are actually beneficial to plants so this system seems ideally suited to our needs. The system has been approved by the Colorado State Department of Health.

Sun-up thus offers comfortable housing for 14 students and a faculty family. It minimizes operational costs, eliminates most traditional maintenance (heating systems and exterior paint), and provides, in addition, an educational experience that not only heightens our awareness of our impact on the resources of the world but offers an attractive and comfortable alternative as well.



MAIN LEVEL FLOOR PLAN



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Issues and Opportunities In Passive Solar Development

Wayne and Susan Nichols
Santa Fe, New Mexico

ABSTRACT

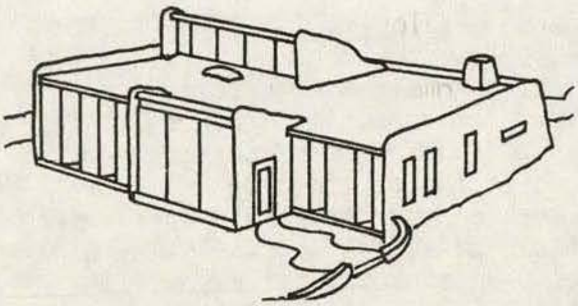
Passive solar construction represents an interesting opportunity for builders, designers and developers throughout the country. The demand in America for low energy design and construction techniques will unquestionably increase over the next decade. In our market we know passive solar homes work and are salable. They work so well, in fact, that we are convinced passive solar will play a major part of our government's continuing energy initiatives. The opportunity is clear. Our national goals will switch faster than our capacity to design and build low energy structures. Those experienced in these techniques will have a sizable advantage over those just entering the field. The key to the present opportunity in passive solar is an understanding of how the technology fits with residential and light commercial real estate.

This paper will first describe the work we are now doing in Santa Fe. It will then discuss the state of the art of passive solar and some of the marketing principles in real estate as they affect the acceptance of passive solar structures. We will conclude with a discussion of how marketing may affect key decisions in the design, development, financing and sales of passive solar homes and subdivisions.

Commercial builders in Santa Fe are using more passive solar techniques in custom construction. Susan and I are small builder/developers and are the first in our market to use passive solar as the center of a development program for an entire project. The project, La Vereda, is 19 passive solar homes on 10 acres within the city of Santa Fe.

We have just completed First Village, a luxury solar development of 8 homes on 40 acres, 4 miles south of Santa Fe. Passive solar has played a dominant role in our design, construction, and marketing plans. We feel that our success to date is a result of properly mixing passive solar techniques with open space site development, water conservation, quality construction; and, a general business philosophy of environmental concern and responsibility.

The 8 home First Village was started four years ago as a laboratory to test solar acceptance in a real market situation. All 8 homes are sold from prices of $95,000 to $190,000 with house construction costs in the $50 per square foot range. In 1975 very little was known about passive solar design and construction. The high priced custom homes in the First Village project allowed us to experiment with very little risk.



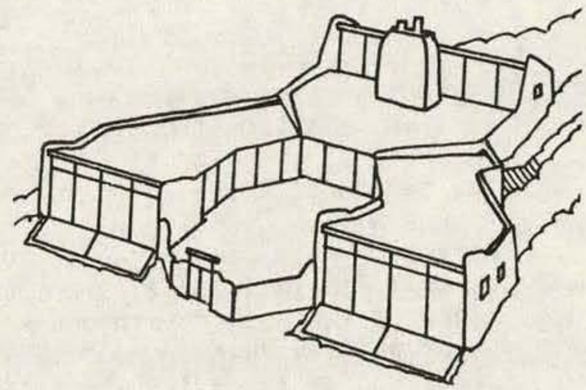


Fig. I

Unit #3
First Village

Unit #4
First Village

Our next solar development "La Vereda" is an in-town R-2 planned unit development with 19 homes in three small solar villages or clusters with solar and water conservation required by deed covenant. The unit prices will be $95,000 to $130,000. The sales price, exclusive of land, will be in the $42 to $45 per square foot range. Lot prices are $20,000 to $25,000 for 1/2 acre of land.

There is substantially more risk in pioneering passive solar in this somewhat lower cost, urban market. The trick will be to preserve that important sense of quality, consistency, and responsible development at these lower price ranges.

Passive solar, like any new technology, will go through stages of evolution in the market. Our First Village subdivision is the first generation in this evolution. Here we have proven that the passive solar technology works can be adapted to local construction and market standards.

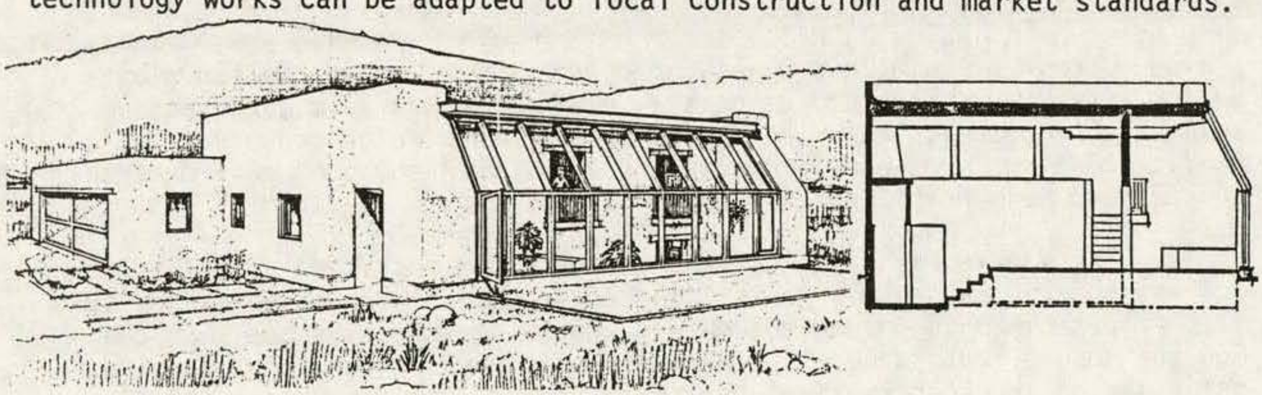


Fig. II Model #4 La Vereda

Model #4 is a 2,000 square foot split level with 90% solar fraction using mass backed greenhouse and rockbed for $120,000.

Our La Vereda P.U.D. is a second generation solar development. The homes will be standardized models with less customizing. Our emphasis will be on production, and cost effective passive solar construction details.

The third generation of passive solar development is the multi-family market. We will accept for this challenge once the optimum construction details have been identified, for cost and thermal performance.

Passive Solar is Simple:

Passive solar heating is a simple design and building process that can be incorporated into any structure whose heating load is skin dominated such as residential or light commercial. The concepts are not difficult: face the building south; place glass on the south side to let the winter sun in; build substantial mass into the interior of the structure to absorb and store the heat for night time use; and add moveable insulation on the south glass so the heat is trapped in the structure at night and heat loss from the glass reduced. These are principles that any builder or designer can use in his own climate to achieve rather startling results in heating energy conservation: such as 70 to 90% over conventional structures.

Cooling:

Passive solar techniques for cooling are not as advanced as for heating. In cooling we are able to cut the energy load substantially with insulation, shading, venting and earth sheltering. With the exception of roof ponds, there is not yet a set of passive techniques that can completely eliminate cooling loads or dehumidify.

HUD Program:

The HUD solar demonstration program has been very helpful to us in our own operations. The funds provided by the demonstration grants have helped us meet payroll more than once over the past four years. Besides the money, the HUD program has provided several other benefits: most important, HUD has acted as a network of information on solar activities throughout the country. By being a part of the program, we have been plugged into the network. This has allowed us to measure our own goals against everything going on in the industry. The whole solar field has moved very quickly. HUD understands builders and builder's problems better than any engineers or program planners. They have been quick to give us either positive or critical feedback and are sensitive to the inexact nature of the residential construction process.

HUD has been essential in the development of our own strategic plan. The decision to switch from active to passive systems construction evolved from HUD's monitoring various active system results around the country.

HUD's research on solar buyer profiles has also been useful in validating our own marketing plans and understanding solar buyer preferences and characteristics. It would be a great misfortune to solar technology if HUD's role were reduced or eliminated.

The Passive Solar Market:

Passive solar is a real estate product. It affects value and the use of real property. The long-term potential of passive solar depends on how it fits with overall real estate market trends; and there is no question that reducing energy consumption is a trend in the building business.

In the residential market builders and developers will use passive solar only if it can be proven that it works, it is cost effective, it is acceptable aesthetically to buyers, and it gives the builder a differential advantage over his competitors in the local market. Builders are not quick to adopt new technologies and with good reason. The large amounts of money and lead times involved can make a single mistake financially disastrous.

Product Life Cycle:

Passive solar is a new product and will follow a predictable pattern called a "product life cycle." The concept of a product life cycle is helpful in understanding where and how passive solar will be adopted by builders and buyers over the years. The product life cycle starts with a few brave souls who experiment with something new. These are called early innovators or adoptors. They do original research and act to model the product for the next group of buyers called middle adopters. The middle adopters rely on the early innovators to test the product and demonstrate its value. The late adopters are the last to use something new and usually wait before they buy until late in a product's life when prices have dropped. Passive solar has all the earmarks of a successful new product. We are still in the early innovator stage which is why interest is focused on customized buildings involving professional architects. Solar buyers are people who are interested in new things and can afford them. As passive solar matures, we would expect to see the focus shift from custom buildings to tract and mass produced housing. It is the builder/developer who must carry the passive solar ball through the middle adopter stage of its life cycle.

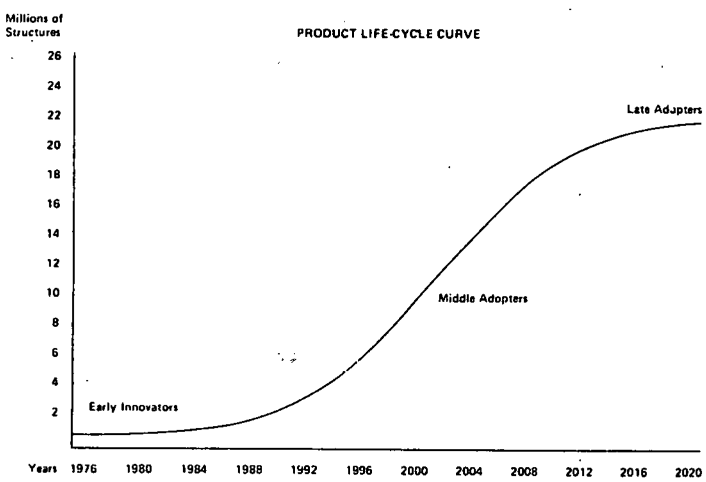


Fig. III Possible Product Life Cycle Curve for Passive Solar Acceptance

Match the Product and Market:

Successful selling of passive solar requires matching the real estate product with those buyers who are most likely to buy it. It would be a mistake to develop a passive solar home designed to sell to late adopters. The trick in marketing a passive solar home is to first identify the market segment and then design a product to fit the segment. This is especially difficult in real estate where the product is a mix of location, design, price, construction, financing, and development approach. The successful passive solar home is an interdisciplinary systems problem that must blend each of these interdependent components into a single solution. It is no wonder that builders are hesitant to plunge full bore into the market place with passive solar products.

State or Market:

There is a natural process of market acceptance for passive solar going on right now. The HUD and DOE programs such as the last Passive Solar Design Competition are doing a great deal to accelerate builder acceptance. In one year there will be hundreds of passive solar residences scattered throughout the country in major markets. These homes are significant because they have been carefully screened by the evaluation teams to pick the best examples of salable, regionally appropriate, high performance passive solar homes. HUD, SERI and DOE have done a good job in their selection. The infusion of these high quality carefully considered passive solar designs into the market place could accelerate growth of the technology through the life cycle stages.

In plain language, the product could go very quickly from custom homes to the total development stage. We have found in Santa Fe that most of our sales are word of mouth; and feel this has resulted from our taking a leadership role in our market and introducing passive solar first and at a visable scale. We would recommend this to other small builder/developers who would like to establish an innovative, quality reputation in their market. Strategically, the best point of entry into a new product market is just before it moves into the middle adopter stage. At this stage the experimentation has been done and the market is just entering a growth period. If that growth accelerates as the result of an effective federal program, it will be increasingly difficult to achieve visibility in your market. A good plan is to start now with a few homes to test the water, learn from your buyers, and get your local reputation established.

Who are the Buyers?:

Housing Magazine called them the hottest segment of the residential market. "The young professional." They buy the small car, read magazines, have planned families, are between 35 and 44 years old, and they have the money. In the next ten years, their number will increase from 28 million to 40 million. And, they will control $1 out of every $4 of personal income.

In terms of real estate, the war babys, grown up, represent the primary market for new residential construction for the next ten years.

This is a very significant trend. The number of households in the 35 to 44 age group will increase as follows:

	1979	1985	1990
Households	12,236,000	15,538,000	18,224,00
Average Income	$24,808	$27,326	$29,485

Within this group there is a smaller group that is attracted to passive solar. The Franklin Institute has analyzed buyers of solar homes under the HUD program. SERI has done similar studys and they confirm our own sales experience in Santa Fe. We suggest the following profile as the target segment for passive solar.

Solar Buyer Profile

1. Age – 30 to 45/ 55 and up
2. Children – 0 to 1.5
3. Income – $25,000 plus (combined)
4. Employment – Two jobs, professional, self-employed
5. Education – Advanced Degrees

Concerns – Quality, Environment, and Flexibility

Fig. IV Passive Solar Buyer Profile

The literature and our experience indicates another important group which is older households moving to a smaller home and looking for relief from a diminishing fixed income. Our sales at La Vereda are running about half older households and about half younger couples in the 35 to 44 age bracket.

Buyer Motivation:

In our experience, passive solar buyers see themselves as "responsible". This is why they buy a solar home; and they look for the same thing in a builder/developer. They are sensitive to quality and expect the home design, the construction, site planning, and solar approach to be carefully thought through and consistent with their expectations of responsible home builder. Part of the appeal of solar is a backlash against what these buyers consider irresponsible builders. The purchase of a passive solar home is, therefore, a personal act with wider social and community implications.

We feel there are four components to the buyer motivations for purchase. They are:

Buyer Motivations

1. Image
2. Economics
3. Comfort
4. Information

Image: is a primary motivation for the early solar buyers. To be first in the neighborhood with something new is a strong incentive. The personal and social implications of owning a solar home is also an important motivation.

Economics: of energy savings will be increasingly a motive for purchase. The economics of solar heating is still somewhat cloudy. As fuel prices and national concern rise and as subsidy programs are extended to passive solar, the economic benefits will be more apparent and the motivation stronger. It should be noted that passive solar has real economic advantages in most markets. A lower first cost and non-existent operating and maintenance cost for equal performance gives passive solar the competitive edge over active systems in any economic model used.

Comfort: is a key to passive solar system's acceptance. A properly designed home with sufficient interior mass, will give good solar heating fractions with very little interior temperature swings over a daily and yearly cycle. The interior mass is basically a radiant heating system without the on/off blasts of hot air from forced air furnaces. In most markets, a radiant system is the preferred high quality heating technique and this is a real plus for the passive solar approach.

Information and control: are an important motivation for purchase. Selling the passive solar home is selling information to the buyer about how well the system will perform and the cost savings that will result. We see ourselves as selling a little energy company to the buyer. He wants to know how much extra he is paying and his expected return. The more information we can give, the happier he is and the easier the sale. Detailed solar engineering, incremental cost analysis and economic projections all help to reduce the buyer's fear of doing something new and untried. Good information is essential to the successful passive solar marketing plan. The basic need that underlies demand for passive solar is the growing sense in America that things are out of the individual's control. Passive solar offers a degree of self-sufficiency to the buyer and increased control over the uncertainties of his immediate environment. Building whole projects of passive solar homes also adds the critical dimension of "community" to this sense of self-sufficiency and control which in turn enhances the buyer's motivation.

Check List:

The following checklist is offered as a guide in putting together a successful passive solar development:

I. Real Estate Principles

Remember, good passive solar design will not save a badly conceived real estate project. It will give a good project an important differential advantage in its local market.

a. Location: is the most important aspect of real estate. Pick a location that will appeal to your target segment. Error on the side of quality.

b. The Target Segment: should be carefully determined. Who are the prospective buyers in your local market and where in town are they now buying. Prepare a buyer profile to act as the basis for design, pricing and development approach.

c. A Neighborhood Profile: is also important. Once the location is selected, survey all existing adjoining developments for architectural style, floor plans, price, amenities and types of buyers. It is important to match the target segment with a neighborhood where these types of people are actively buying.

II. Solar system design

a. Architectural style is the key to successful solar design. The passive solar elements must be carefully fitted into the styles popular in a market. The better the integration of the passive solar elements with acceptable architectural styles the greater the market acceptance.

b. Passive solar techniques are different for each region. The basic approaches are the same nationally but the mix and proportions vary with local climatic conditions. Survey existing passive solar structures in your region and their performances. Talk to builders and users and select the optimal regional solution. Prepare full engineering calculations and sensitivity analysis for your design and systems and see if the solar fraction is sufficiently high to motivate buyers. Cooling and humidity are problem areas that must be considered. We have found that mass backed greenhouses, trombe walls and rock beds give high performance with small interior temperature swings.

III. Development

a. Site Planning is as important in passive solar development as the house design. We believe that the buyer is looking for a developer who respects and preserves the existing landscape and terrain. The cluster type setting and open space planning using the planned unit development approach allows maximum flexibility for house solar orientation. In La Vereda we have four acres for 19 homes and lots, one acre for roads and five acres of open space.

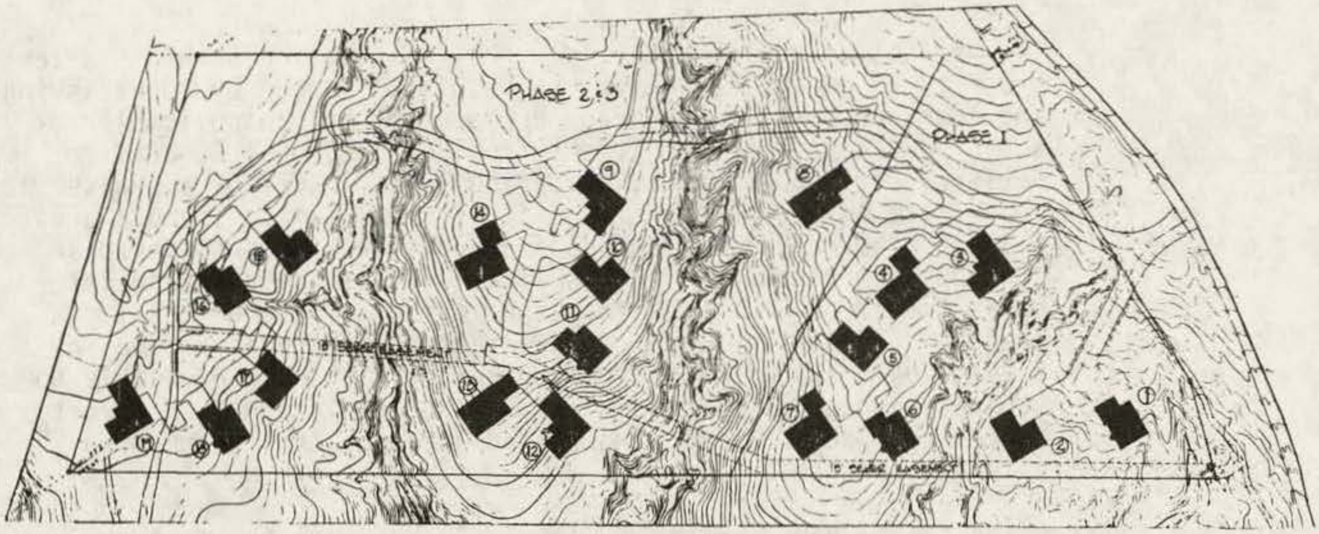


Fig. V. La Vereda Site Plan

b. A homes association is used to own and maintain the open space in all our projects. The Homes Association is also empowered to select and install future energy savings technology if the homeowners so decide. Solar rights are incorporated into the association documents and along with the architectural review are enforced by the association.

c. Community aspects to passive solar development help sales. Buyer resistance to accepting something new is reduced if all the homes are solar. Also, the community can give important visibility to a project. By working closely with local zoning and civic groups, a passive solar development is an important community asset. The local utility, university, or research laboratory may want to participate in designing and monitoring a project giving it more visibility and credibility.

IV. Construction

Is the key to good passive solar performance. Infiltration accounts for half the heat loss in a residence. We use our own crews who are experienced in our rigorous quality standards for vapor barriers, insulation installation, and other critical details. Remember the builder is the solar manufacturer, and passive solar is primarily a construction process technology not an equipment technology. Choose a builder experienced in energy saving construction techniques in your area.

V. Financing

The project size will determine the financing approach. Smaller projects of one to six homes can best be financed by local savings and loans or banks. On larger projects it may be advisable to get a permanent loan commitment from your regional Federal National Mortgage Association office. The lender or appraiser is your first sale. We have found it very helpful to spend a great deal of time educating lenders and appraisers on passive solar construction techniques and benefits. It is important to get these people on your side from the beginning. To do this, we prepare an elaborate lender presentation package as an aid in a full-scale lender education program. It is also advisable to separate energy conservation costs like insulation from direct incremental solar costs. Most loan and appraisal forms make this distinction.

Attention to the above issues will help in avoiding the most obvious pitfalls in initiating a passive solar program. Passive solar heating works in most major markets and it can be successfully incorporated into regionally acceptable architectural styles. The size of the opportunity is a function of establishing a local reputation for expertise in energy conserving design and construction techniques. We suggest taking advantage of this opportunity now.

The Solar Way Building;
A Commercial Solar Demonstration Project Which Uses a Phase Change Material for Thermal Storage

Charles L. Bliege P.E.

INTRODUCTION

The purpose of this presentation is to share design and construction experiences of an active air solar system which uses a phase change material for thermal storage.

The primary goal of this solar project is to demonstrate that solar energy is a viable source for space heating, water heating and solar cooling in Oregon's Willamette Valley. A secondary goal is to demonstrate the use of a salt-hydrate eutectic, phase change material in a solar heat storage application.

The Solar Way building is a two story office building with 4000 sq. ft. of office space and a full basement of 2000 sq. ft. The two upper floors house five offices. The basement is presently intended to be used as storage space but can be readily converted to additional office space. The building is energy efficient, constructed using 2 X 6 wall framing, R-19 insulation in the walls and R-38 insulation in the upper ceiling. Windows are double glazed and glass area is kept to a minimum to minimize heat loss.

It is projected that the solar system will produce:
66% of the combined annual space heating and water heating needs.
34% of the annual cooling needs.

SYSTEM DESIGN

Collectors

The collector system selected consists of forty-eight (48) flat plate air collectors manufactured by Valmont Energy Systems, Inc. Valley, Nebraska. Nominal effective collector area is 936 sq. ft. The collector frames are made with 18 ga. steel, painted with a heat resistant black paint and prebaked to minimize outgassing. The double glazing of 1/8 inch tempered glass is mounted in a high temperature EPDM sealing gasket. This gasket is slightly vented to control moisture which might become trapped between the two glass panes.

The absorber plate is 28 ga. corrogated steel protected by a nickel plating. The absorbing surface is coated with black chrome which has an absorptivity of 95% and an emissivity of 10%.

Collector trim is made from a 14 ga. galvanized steel and finished with a dark bronze color flurocarbon (Kynar) for long life.

The collector system was designed to withstand stagnation temperatures without causing damage to either the collector or to the structure to which it is attached. The thermal expansion characteristics of steel and glass are nearly identical, making them quite compatible. The structure is protected from the heat of the collector by three inches of semi rigid fiber glass insulation rated for 400°F, (Owens Corning #703 unfaced). This insulation is used to prevent outgassing at high temperatures.

The collectors are mounted on a Vertical wall facing 12° East of South. Vertical wall construction was selected to facilitate lower construction costs. Studies by Los Alamos Scientific Lab have shown that major deviations from optimum tilt have only a minor effect on annual performance with systems which provide more than 50% of the annual heating requirements.

In this instance annual performance projections are affected by less than 5% with the collector tilt at 90° instead of at the optimum of 60°. Vertical collectors allow easy implementation of reflectors placed on the ground in front of them. In addition, solar collection efficiency drops in the summer due to high sun angle and presents less of a potential problem with overheating.

Phase Change Storage

Due to the fact that this is the first project in the D.O.E. commercial demonstration program to use a phase change material for storage, some time will be devoted to developing background materials to facilitate a better understanding of phase change materials (PCM's).

(1)(Because of the time dependent nature of solar energy and building heating loads, an efficient method of thermal storage is necessary for solar energy to be practical.

With liquid type solar collectors, the traditional method of storage involves a large insulated tank of water which is heated either directly or by means of a heat exchanger. This solar heated water is then used to heat the conditioned space through a fan coil or is boosted in temperature with an auxiliary source for delivery to the area to be heated.

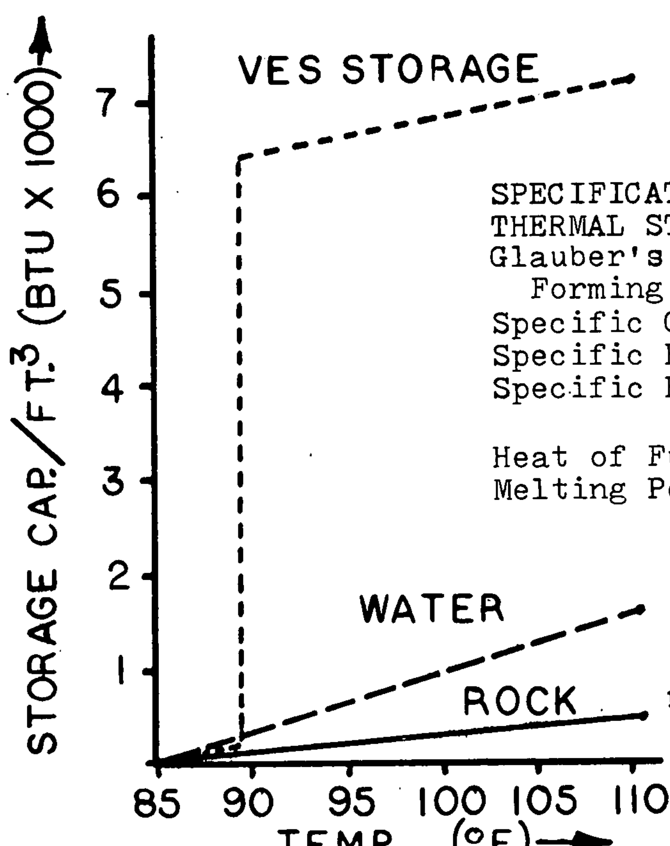
With an air type solar system, storage is usually accomplished by means of a rock bed. This method involves construction of a storage bin using either wood frame construction, concrete block walls, or a poured concrete chamber. Appropriate air plenums are built into the box. The structure is then filled with smooth round stones approximately 1½ inch in diameter. Solar heated air is blown into the bin and circulates through the rock transferring heat. Heat delivery to the conditioned space is accomplished by circulating return air through the stones where it is heated and then ducted into the conditioned space.

Both of these methods involve heat storage in the form of sensible heat. Sensible heat describes the phenomenon whereby energy absorbed or released by a material results in a temperature change of the material.

A third method of thermal storage exists that involves the use of a phase change material. When a material changes state from a solid to a liquid at its melting point, it will absorb large amounts of energy with no change in temperature. This energy is called latent heat. For instance, one pound of ice at 32°F will absorb 144 BTU's as it changes into one pound of water at 32°F. The use of a PCM would allow much more energy storage per unit volume than sensible heat storage methods.

Sodium sulfate decahydrate, also known as Glauber's Salt is one such PCM. Because it melts at 89°F, it is suitable for use as solar storage. The salt absorbs a large amount of energy in order to melt at 89°F. In the temperature range of 85°-110°F, the salt will store 5 times more energy than water and 14 times more than rock for an equal installed volume of material. (See Fig 1)

There are two major benefits from this. 1. The required volume for storage is greatly reduced. 2. Solar system efficiency is improved. Efficiency of a solar collector is dependent on the temperature difference that is developed between the inlet and outlet temperatures of the operating fluid. With sensible heat storage methods, the temperature of the returning fluid is constantly rising as more energy is put into storage. PC storage, however, operates at a nearly constant temperature resulting in a low return air temperature to the collector.



SPECIFICATIONS:
THERMAL STORAGE SYSTEM
Glauber's Salt($Na_2SO_4 \cdot 10H_2O$)+ Crust Forming Stabilizers
Specific Gravity................1.46
Specific Heat (solid).......C_{ps}=.35
Specific Heat (liquid)......C_{pl}=.65

Heat of Fusion........ 100 BTU/lb.
Melting Point .... 89°F

FIG.1
RELATIVE STORAGE CAPACITY OF 1 ft.³ OF MATL. (installed).

note: assume 35% air passage for rock and VES storage.

FIG. 1

In addition to the benefits which are to be derived from the use of PC storage, certain problems exist as well. Nearly every solar publication available describes PC storage as an experimental concept, not yet demonstrating reliability. One of the main problems has to do with stratification or breakdown of phase change materials. The chemical composition of Glauber's salt consists of 44% Na_2SO_4 and 56% water. As a solid, this material exists in a homogeneous crystalline form. When it is melted and heated above 90°, however, approximately 15% of the sodium sulfate will precipitate out of solution as a solid, with the remaining mixture being composed of a saturated solution of sodium sulfate and water. This separation occurs because the anhydrous sodium sulfate is twice as dense as the Glauber's salt. When cooled, the mixture will begin to freeze with the initial crystal growth occuring at the interface between the solid and liquid solution. As the crystal growth progresses, it interferes with the complete recombination of the material resulting in a loss of thermal storage capacity. This separation is permanent unless the mix is agitated to promote recombination.

The tremendous benefits afforded with the use of PC storage for solar energy has drawn considerable attention aimed at the problems associated with its use. The G.E. Co., is working to develop containerization of Glauber's salt in a stainless steel drum that is continually rotated to prevent separation of the salt mixture.

MIT is experimenting with thin layers of a eutectic mixture contained in a waterproof polyester concrete ceiling tile. Dow Chemical has chosen to work with calcium chloride hexahydrate, a PC material that melts at 81° and does not have problems of stratification. This material is, however, both corrosive and toxic.

These various approaches are too costly, too dangerous, or impractical. The foremost authority on phase change thermal storage in this country, and probably the world, is Dr. Maria Telkes. Her involvement in solar energy goes back over 50 years. She has been involved in solar thermal research with MIT, the University of Delaware, and currently is associated with the American Technological University in Killeen, Texas.

Dr. Telkes has developed a process which prevents the stratification of Glauber's salt by means of a thickening agent. This mixture is packaged in plastic containers and has been subjected to over 1000 freeze-thaw cycles in accordance with approved ASHRAE and NBS testing procedures. No loss of thermal capacity or degradation occured. This many cycles would be the equivalent of approximately 10 years in a solar heating system application.)

The storage system used in this project uses this process and is manufactured by Valmont Energy Systems, Inc., Valley, Nebraska. It is manufactured under exclusive license from Dr. Telkes and American Technological University.

The PCM used is the Salt hydrate sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$) + Crust Forming Stabilizers.

This system provides a means for the salt crystals to become self-supporting as well as overcomes stratification problems that many have sought to overcome. In this process a crust is formed around each crystal of the solid salt hydrate by chemical means. Above the melting point the crystals melt in their crust-shells, but due to the small size of each encrusted crystal, stratification is negligible. The entire structure is self-supporting, even when the crystals are at a temperature above their melting point in the liquid state.

This salt hydrate encrusted-conglomerate is packaged in a hermetically sealed container made by blow molding a high-density polyethylene (HDPE). Fillers are added to the plastic to prevent permeation of water vapor. It is essential that the loss of water through the container wall be reduced to an absolute minimum of 2% during 10 years. It is possible to add 2% excess water to the mixture during initial mixing, which will be lost gradually and permit operation for 20 years, when there will be an actual water loss of 2%.

The particular design of the container used to contain these salt hydrates is end filled and then permanently sealed with an induction type seal. The container design facilitates self stacking in the storage compartment and allows for a typical air passage of 35%. (2)

The storage configuration used here contains 384 containers of the PCM. The containers are approximately two feet long by one foot wide by two inches thick. They are stacked four wide and four long with vertical transite support dividers between each row of containers. Once the containers are stacked twelve high, a horizontal support shelf is placed across the vertical dividers so that the next section of containers can be stacked as the ones below.

Storage Capacity:

Heating—9,676 BTU @ 89°F - 89°F (28.9°C-31.7°C) Sensible
691,200 BTU @ 89°F (31.7°C) Latent
134,784 BTU @ 89°F - 120°F (31.7°C - 48.9°C) Sensible
835,660 BTU TOTAL @ 120°F (48.9°C) Latent + Sensible

Cooling—72,576 BTU @ 50°F - 80°F (10.0°C - 26.7°C) Sensible

ENERGY TRANSPORT/CONTROLS

Energy Transport

The energy transport system consists of a fiberglass duct system fabricated using the Micro-aire™ duct system by Johns-Manville. This system minimizes air leaks and noise as well as provides insulation built into the system. All motorized dampers in the system are a Lo-Leak type. Losses are specified at less than 20 CFM per square foot of damper at 1" pressure (1% at 2000 ft. approach velocity).

Controls
The solar collection and distribution system is controlled by a "Homemaster" solar controller by Solar Control. Functions not provided by the controller were designed and installed by HITEK, Inc. The Solar System has nine operating modes.

1. Collector to heated space.
2. Collector to storage.
3. Storage to heated space.
4. Domestic hot water pre-heat.
5. Auxilliary heat.
6. Continuous air flow. (Nocturnal cooling)
7. Auxilliary cooling
8. Excess Heat Venting
9. Fan only

SPECIFIC CONTROL DESCRIPTION:

Refer to the system schematic (Fig 2) for clarification.

Collect and Store Mode:
When pre-determined temperature differential between collector and storage exists, the collector fan turns on and moves heat into storage.

Collect and Heat Mode:
When solar energy is being collected and heat is called for by room thermostats, the controller will control dampers as indicated to direct the heat to the required areas. The solar system is tied into the back-up heat distribution system as is indicated in Fig 2.

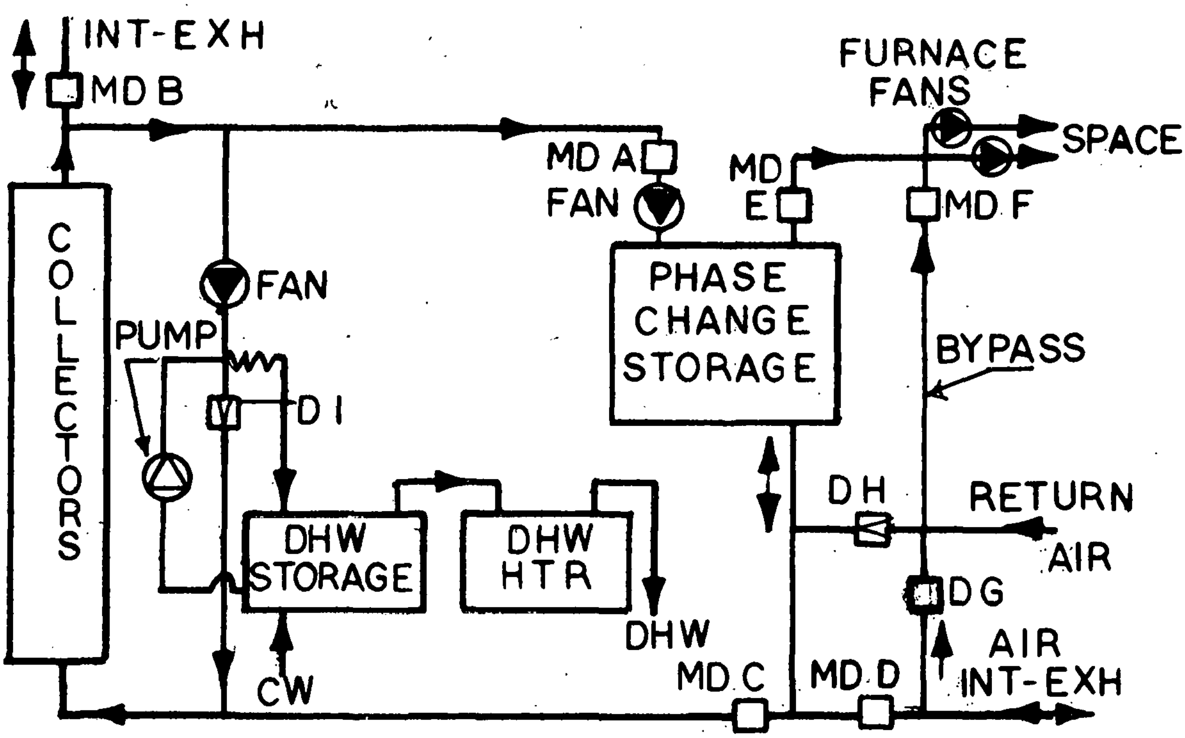


FIG 2 SYSTEM SCHEMATIC

Heat From Storage

The heating system consists of four zones, each with their own thermostats. There are two backup electric furnaces with back-up air conditioning. Each furnace system handles two zones. Individual thermostats control zone dampers and signal the controller to turn on the appropriate fan/furnace/air conditioner according to the mode requested by the thermostat. When heat is in storage, the fan in the back-up units pull the heat from storage and distributes it to the required zones.

Auxilliary Heating

In this mode of operation, heat is called for by room thermostats and is provided by the auxilliary furnaces. The controller provides a two stage output for control of the auxilliary furnaces. When the controller determines that no heat is in storage or being collected it controls the auxilliary furnaces such that the required heat is delivered to the room demanding heat. The storage is bypassed when W_2 is called for, and cold storage is less than 70°F.

Domestic Hot Water Heat

Domestic hot water is heated when solar heat is being collected, depending on the collector temperature and the temperature of the water in the pre-heat tank. When the collector is warmer than the water in the pre-heat tank by a preset differential, the small fan will turn on to move the solar heated air through the heat exchanger. Also a pump will turn on to move water from the preheat tank, through the heat exchanger and back to the tank.

Continuous Air Flow (Nocturnal Cooling)

In this mode the fans in the Auxilliary furnaces turn on, dampers A, C and F are closed and dampers E and H open for day "free cooling" operation. Heat is removed from the building during the day and is stored in the storage room while the "cool" is moved into the conditioned space. In this mode of operation only sensible heat is used. The amount of cooling available is dependent on the size of the storage since the specific heat of the Valmont Salt Hydrate in solid form is 0.35 BTU/lb°F.

It is also limited by the outside night air temperature, since this is how the storage is cooled. At night, dampers A, B and D open, damper C closes and the collector fan turns on. Cool air is brought in from the outside through the vent at damper B. This cool air "flushes" the heat out of storage and exhausts it through damper D and out the exhaust vents on the south side of the building. The Willamette Valley has quite cool nights in the summer and therefore acceptable performance is expected with this cooling system. It is projected that the nocturnal cooling system will provide 35% of the annual cooling needs.

Auxilliary Cooling

This mode of cooling is activated when the free cooling mode cannot keep up with cooling requirements. Request for the second stage of cooling by room thermostats results in damper E closing and damper F opening, while the back-up air conditioner compressor is turned on. In this mode the storage is completely bypassed for more efficient operation.

Fan Only

In this mode, the fans in the back-up system can be used to circulate air in the building while bypassing storage and providing some outside fresh air via the make-up air inlet.

Excess Heat Relief

In this mode of operation, Dampers B, C and D open to allow cool outside air come into the collector array at the bottom and exit out the top. This will occur when T col $\geq$ 185°F. The Valmont collectors are designed to withstand stagnation temperatures exceeding 400°F, but the free air convection cooling process used here will serve to lengthen system and building life.

SYSTEM INSTALLATION/START UP

System installation went quite well, thanks to a good installation manual and training provided by the manufacturer. Exceptions having to do with the fact that we had some re-work to do because installation had originally started with intentions of using a solar system provided by a different manufacturer are covered in the problems section.

Collector installation procedures provided by Valmont require that the collector wall (or roof in the case of a roof installation), be sealed air tight prior to installing anything on that surface. This is accomplished by caulking all cracks and joints with a silicone caulk. Likewise, all joints in the collector array are caulked and sealed; then before glazing is installed the whole collector plenum between the wall and the collector absorber plate is pressurized with a small fan. All of the joints are sprayed with a water/soap solution to enable locating any leaks in the system.

Air leaks cause bubbles to appear at their location when the water/soap solution is sprayed over them. Once located, these leaks are sealed using a 400°F silicone caulk. By minimizing air leaks, energy loss is reduced, thus making the system more efficient.

The collector installation is completed by installing the glazing and the trim. Silicone Caulk is applied to the perimeter trim/glass interface of each collector.

At initial start up and test, the air flow into and out of the entire collector array is balanced. This is accomplished by obtaining an average velocity for each inlet/outlet port. Balancing dampers at each port are then adjusted and the procedure is repeated until flows are within 10% of each other. Fan speed is then adjusted if necessary to provide the design flow of 3 CFM per sq. ft. of collector.

Storage installation went very smoothly and quickly. The 20 lb containers of the salt hydrate PCM are self-stacking and easy to handle. Flexible metal air dams are installed at the top of each stack to prevent air from bypassing the containers as they settle during the first few phase changes.

Air flow across the container array was checked at start up and found to be quite uniform. During initial testing, it was found that typically there was a 40°F temperature drop across the storage during the collect and store mode. As the storage went through the phase change, the outlet temperature stayed near 90°F until most of the containers of Salt hydrate had phase changed. Then, the temperature began to rise as in a storage system which uses sensible heat storage.

PROBLEMS AND SOLUTIONS

During the final design review and initial installation several problems surfaced with the product originally specified. The nature of these problems was such that it was determined that if the project were to continue with that product the project would not meet the goals of the demonstration program. In order to meet these goals, another product by the manufacturer herein was specified.

Collectors

The original collector specified incorporated a wood frame, to which a metal absorber plate was fastened. Commercial building codes require that wood materials not be in contact with metal if the metal can reach temperatures of over 150°F. The local building inspector would allow this collector if the wood material were fireproofed. The collector manufacturer was not able to provide a fireproof collector jamb, therefore another collector was dictated.

A more serious problem is that of the thermal expansion of the absorber plate as compared to that of the wood frame. Various humidity and temperature conditions can cause serious buckling of the absorber plate and eventual separation from the wood frame, shortening the collector life.

The collector wall was framed to accomodate the original system and required rework in order to install the new system.

The collector used, manufactured by Valmont Energy Systems, Inc. was able to meet all building codes without difficulty. In addition superior performance is projected with this collector.

Phase Change Storage

Probably the most unique thing about this project is that it uses a phase change thermal storage system. Although many have attempted to use these salts over the years, most have run into problems with stratification, where the latent heat storage capacity drops to about 55% of its theoretical capacity. A preliminary (July 1978) test report by the National Bureau of Standards indicates that the storage system originally specified stratifies within four phase changes. (3)

Personal experience at the time of the final design review with the previously specified phase change storage system provided evidence of stratification as well. In addition to the stratification problem, failures in container seals and defects in containers as molded has resulted in leakage of the salt mixture from containers, especially while in liquid form in as many as 25%

of the containers in a given storage system. In addition the manufacturer had not provided replacements under their warranty program.

The Salt-hydrate eutectic selected to replace that which was originally specified uses a method to overcome stratification (2) which also greatly reduces the possibility of leakage due to defective containers by the nature of the encrusted-conglomerate structure which provides a semi-weight bearing substructure.

Control System

Optimal control of the solar system through all modes of collection, storage and distribution is a major problem. Many controls are available and all functions desired can be implemented with "off the shelf" components. A control system that can provide all the control options necessary with much less cost and complexity is needed. The optimal control system will also provide all the interface control with the conventional backup system.

The control system for this project became much more complex when the building owner changed to a multi-zone system, for which no funds were budgeted or provided.

Control coordination between the backup heating/cooling system and the solar system has been a problem. Indications are that the "Design-Build" approach applied to the entire solar and backup heating/cooling system would eliminate this problem.

CONCLUSION

The trials of re-design, re-work and installation of the solar system in The Solar Way building have been quite educational, although not profitable.

The performance of the system to date cannot be determined since all functions are just coming on line. Tests made on the phase change storage are impressive. The system promises to yield excellent results in the heating seasons ahead. Since this demonstration project is the first of it's kind to use a phase change storage system, performance results will be of interest to all who design, install and use solar systems in the future.

REFERENCES

(1) P. Popinchalk, Storage Summary, Dealers Manual, Valmont Energy Systems, Inc. (Fall 1978)

(2) M. Telkes and H.P. Mozzer, Thermal Storage in Salt-Hydrate Eutectics, American Section of the International Solar Energy Society, (Aug 1978)

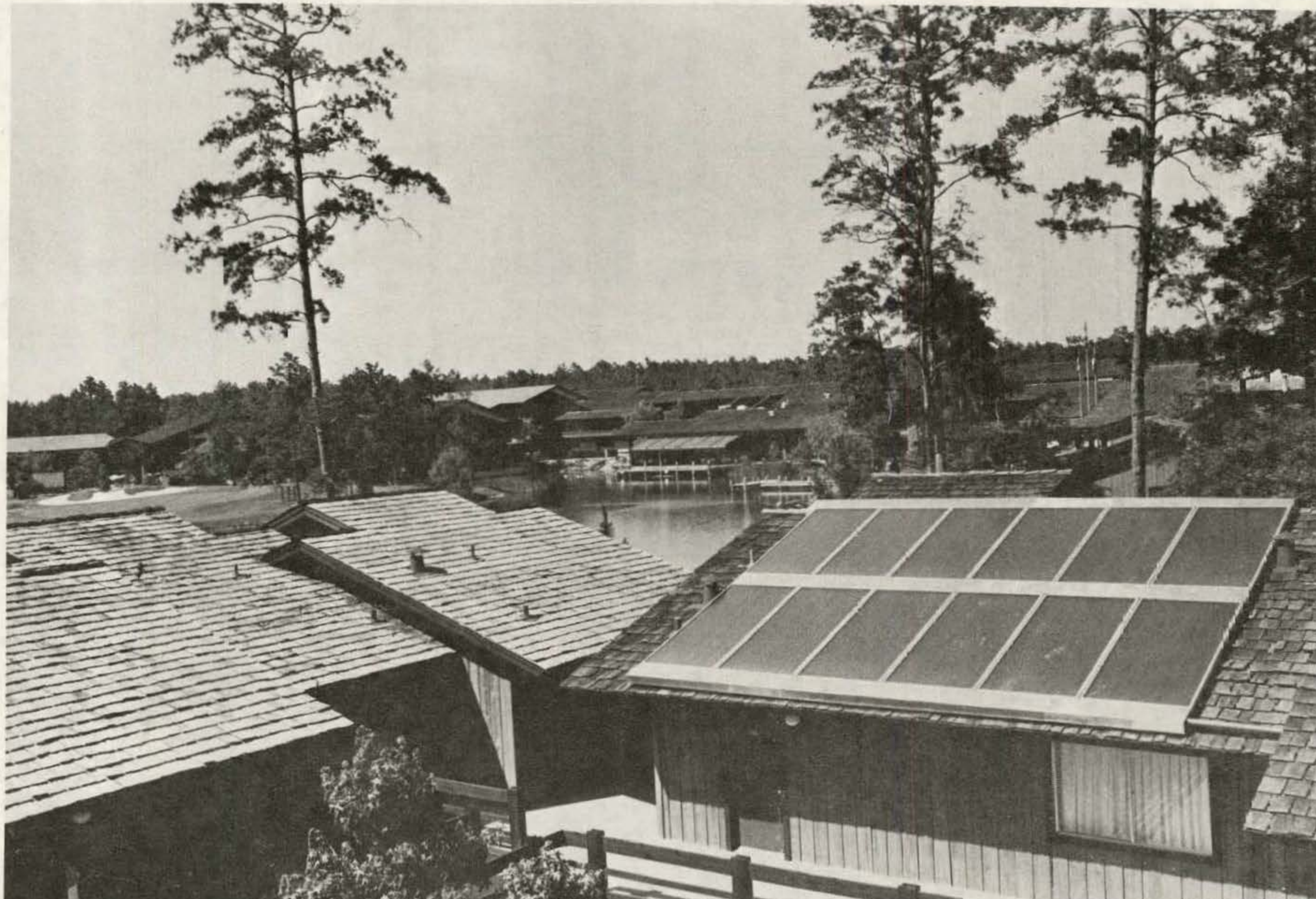
(3) D.E. Jones, Preliminary Test Results For A Phase Change Thermal Storage Device Tested Accornding to ASHRAE Standard 94-77, National Bureau of Standards, (July 1978)

The Woodlands Solar Project

Dale Sartor

Key Word Abstract

Application:	Domestic hot water and pool heating
System type:	Active hydronic
Collector type:	Liquid flat plate
Collector manufacturer:	Solar Energy Products, Inc.
Collector area:	10,260 square feet (aperture)
Storage capacity:	10,050-gallon lined steel tanks
BTU's produced:	2,500 million BTU's per year
Building owner:	Woodlands Commercial Development Co. 2201 Timberloch Place The Woodlands, TX 77380
Architect/Engineer/ Construction manager:	Interactive Resources, Inc. 117 Park Place Point Richmond, CA 94801
Contractor:	Solar Systems of America 1644 Gessner Houston, TX 77080



Typical guest cluster and collector array in foreground; conference center in background.

Introduction

The Woodlands Inn is located in the first village of The Woodlands, a 20,000-acre new town being developed 25 miles north of Houston, Texas, by a subsidiary of the Mitchell Energy and Development Corporation, assisted by the New Communities Division of the U. S. Department of Housing and Urban Development. The Woodlands is a master-planned community which opened its first village to the public in the fall of 1974.

The Woodlands Inn is an executive conference center designed to provide a more effective learning environment for business meetings and conferences. The Inn responds to a growing need for more efficient facilities for training, planning, information dissemination and problem-solving meetings.

Facilities at The Woodlands Inn include: the guest house and 13 guest clusters with a total of 242 units and 532 beds; the conference center with meeting rooms, dining rooms, kitchens, game room, bars, indoor tennis courts and health studios; the wharf (a shopping mall) including additional meeting rooms, dining rooms, kitchens, shops and an indoor ice rink; and the aquatic center with three outdoor pools, one indoor pool and a gymnasium.

A study was made to determine the technical and economic feasibility of solar utilization for domestic water and swimming pool heating at The Woodlands Inn. Solar heating of the outdoor swimming pools was determined not feasible because heat is necessary only a few months of the year (when the sun shines the least) and the back-up heat is provided by natural gas (less expensive than electricity).

Cost-sharing proposals were submitted to ERDA (now DOE) under a special hotel/motel solar demonstration program. The proposals included schematic system designs including selection of key solar components, detailed cost estimates, and computer-assisted thermal and economic analyses. Government funding was provided to demonstrate the practicability of solar energy utilization to the American public and to help lay a foundation for a viable solar industry.

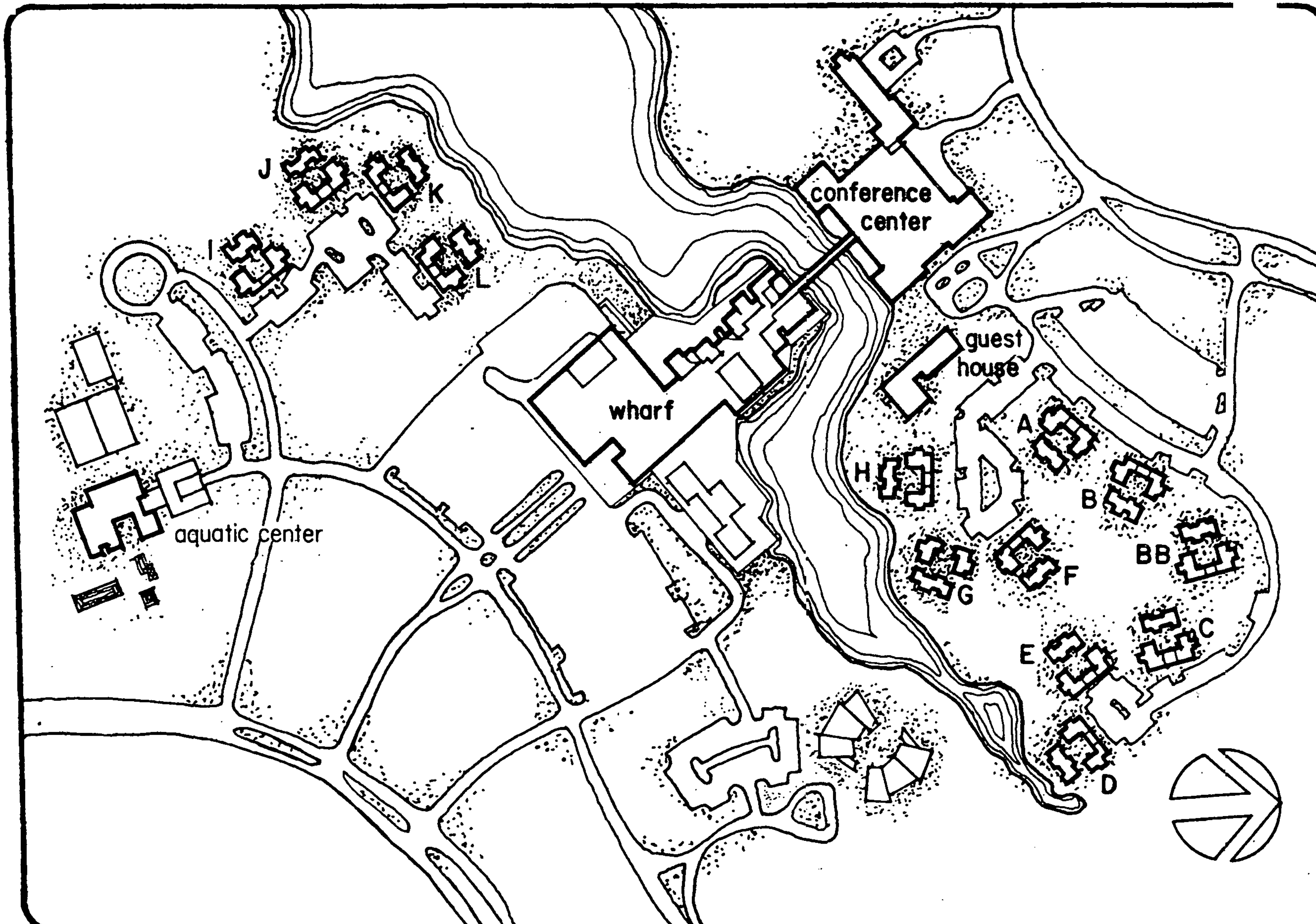
Close to 10,000 square feet of flat plate solar collectors will ultimately be installed to supply over half the water heating needs for the bathrooms, kitchens, spas and indoor swimming pool. The system will save the equivalent of approximately 735,300 kilowatt hours per year at a construction cost of $354,000.

The Woodlands Solar Project provides a show place for 30,000 annual guests to experience solar utilization and see a high quality, aesthetically integrated and cost effective solar demonstration.

In addition, innovative design and construction techniques used in The Woodlands Solar Project will help to advance the state of the art in the commercial solar industry.

Construction Status

The first phase of construction for The Woodlands Solar Project has been completed. The systems on 12 guest clusters now provide hot water supplemented by the existing electric water heaters. Construction is underway on the guest house (additional living quarters) and the Inn itself where hot water is primarily used in the health spa and restaurants.



the woodlands inn

solar heating proposal

fig. 1

site plan

Design Philosophy

The project was divided into three phases and subdivided into six construction bid packages. Work started on the smaller repetitive systems and progressed to the larger, more complex ones.

Guest Clusters

Twelve guest clusters (at first glance, identical) were utilizing one or two 250-gallon electrical water heaters. The solar design involved the retrofit of 360 square feet of flat plate collectors on each unit. Single-glazed panels were chosen due to the low operating temperatures. The size was optimized for cost effectiveness; therefore, the solar fraction (solar contribution) is low. For aesthetic reasons the collectors were mounted parallel to the roof (16^{o} tilt)—not a major penalty in this southern location. The variation of annual performance from the best to the worst orientation (azimuth up to 90^{o} from south) was estimated by computer analysis at only five percentage points. Several collector mounting schemes were developed for the existing shake roofs. Developing an inexpensive, structurally sound, leak-proof mounting system that allows for construction irregularities, e.g., warped roofs, proved to be the most time-consuming (and costly) design detail. The ultimate scheme involves Unistrut members running horizontally several inches above the roof.

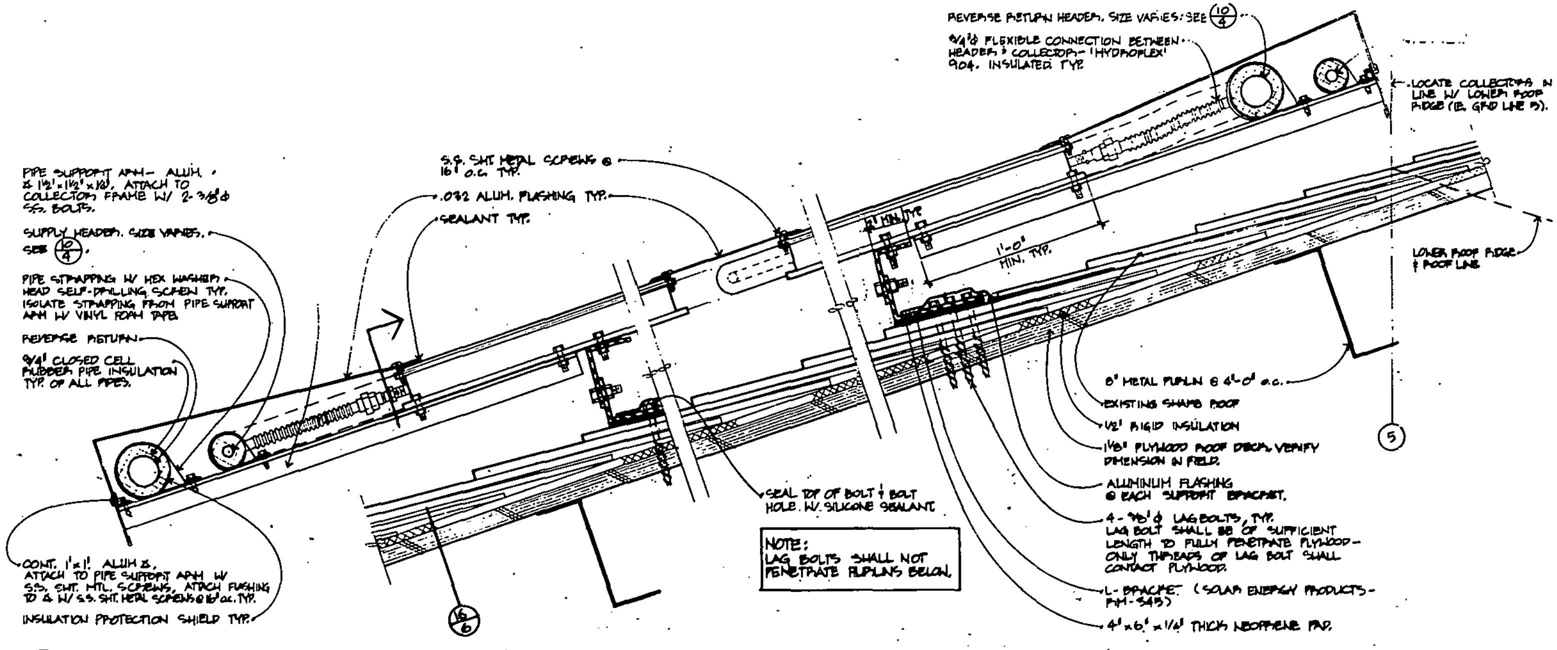
In units where two 250-gallon electric water heaters existed, one was converted to solar storage and replumbed as a preheater. In the other units, where space allowed, 450 gallons of storage were added; otherwise, 325 gallons were added.

Guest House

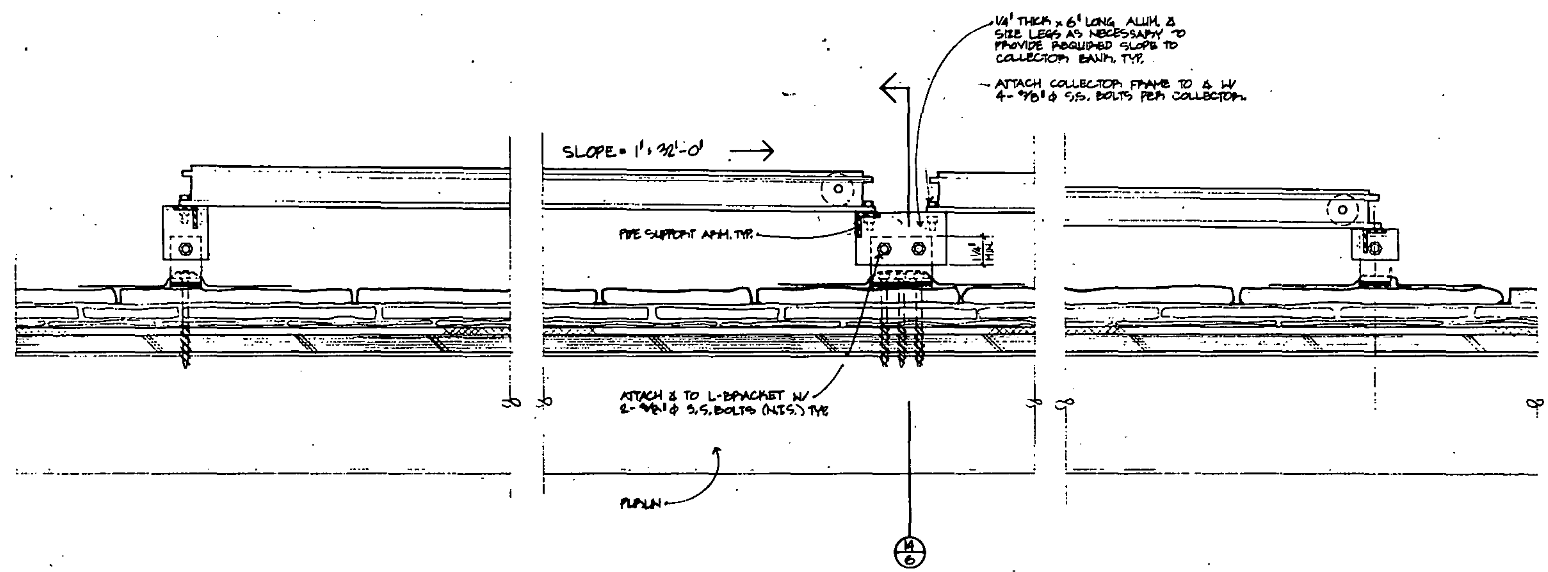
The guest house, a large, motel-like building, is serviced with a single 750-gallon electric water heater. The solar design involves the retrofitting of 840 square feet of flat plate collectors mounted on the flat built-up roof and a new 750-gallon hot water storage tank located adjacent to the existing heater. A sump tank for the collectors is located on the second floor above the primary mechanical room to minimize pump head requirements.

Conference Center

The solar system for the conference center is comprised of 1,620 square feet of collector and the utilization of an existing but unused 750-gallon water heater for storage. Similar to the guest house, sump tanks are located on the second floor.



14/6 ALTERNATE 1 : SECTION - COLLECTOR SUPPORT STRUCTURE 3" = 1'-0"



16/6 ALTERNATE 1 : SECTION - COLLECTOR SUPPORT STRUCTURE 3" = 1'-0"

535

Aquatic Center Domestic Hot Water

The proposed solar project included the retrofitting of 1,200 square feet of single-glazed, flat plate collectors. A water meter installed in the design development phase indicated consumption substantially below estimated. Therefore, the system was reduced 50 per cent in size to 600 square feet. In case the load dramatically increased, provisions were made for future expansion. Collectors will be mounted on the existing shake roof and the sump tank will be located at the second floor level. Two 375-gallon (750 total gallons) storage tanks will be installed in parallel adjacent to and in series with the existing electric water heater.

Aquatic Center Pools

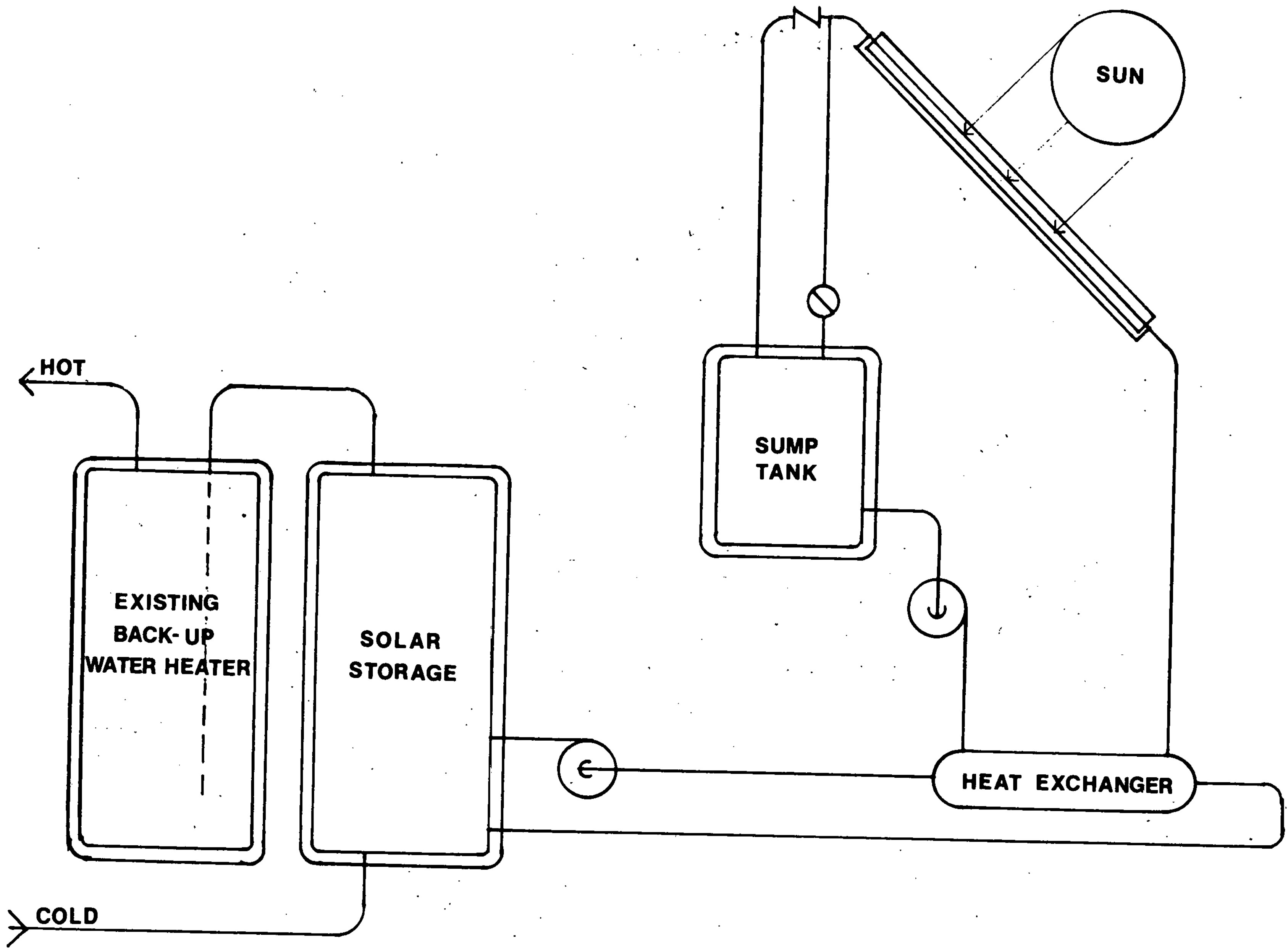
The solar pool heating system will include the retrofit of 2,880 square feet of unglazed absorber plates and an additional 5 HP pump. The collectors will be mounted above the indoor pool. Although provisions will be made for manually switching operation to the outdoor pools, its primary use will be for the indoor pool. Originally, the collectors were to be mounted on the shallow western exposure; but excessive shading due to tall trees led to the location being shifted on to the eastern exposure. In hind sight this is probably better due to a more substantial morning load (generally, the heaters come on in the morning).

All solar systems are technically simple and straightforward. Components were selected and sized to yield the best return per dollar invested. This included extensive thermal and economic analyses of different collector combinations.

System Descriptions

Domestic Hot Water

Solar Collector Loop. When a differential thermostat senses that the temperature in the collectors is warmer than at the bottom of the storage tank, it activates the pumps which circulate water between the collector and the heat exchanger and between the storage tank and the heat exchanger. When the pumps are off, the collectors drain and the sump tank is full. The level can be checked at the site gauge. When the pumps are on, water is drawn from the sump tank to fill the collectors. To facilitate rapid draining, an air vent line is run from the top of the sump tank to the top of the collector array. The collector loop is "closed" with a fixed amount of water and air. An optional low level switch will automatically turn off the pump and sound an alarm if the water level in the sump tank drops to an unacceptable level, i.e., if there is a leak.


SUN
SUMP
TANK
HOT
EXISTING
BACK-UP
WATER HEATER
SOLAR
STORAGE
HEAT EXCHANGER
COLD

Domestic Water Loop and Solar Storage. Simultaneous with the collector loop pump a second pump is activated to circulate water between the bottom of the domestic water solar storage tank and the heat exchanger. Water is drawn from the bottom of the tank and returned to a midpoint. Thus heat is stored in water contained in a pressurized steel tank (lined).

Domestic Hot Water Distribution. As a hot water load occurs, water is drawn from the top of the back-up heater which is made up by water drawn from the top of the solar storage tank. An optional tempering or mixing valve reduces the chances of scalding and reduces the system's heat losses.

Swimming Pool Heating

When a differential thermostat senses that the temperature of the collector is warmer than the pool, it activates a pump which circulates water between the two. A vacuum breaker allows the collectors to drain when the differential thermostat turns off the pump. A check valve prevents draining water from back-washing the filter. An upper maximum thermostat prevents overheating of the pool by shutting off the pump at a set temperature. Energy is stored in the pool itself by allowing the water temperature to fluctuate several degrees.

Innovative Design

The Woodlands Solar Project is the first large-scale commercial application of a solar water heating system utilizing a low-pressure drain-back collector loop coupled to the domestic hot water with a single wall heat exchanger. This system is more efficient, less expensive, more reliable and will require less maintenance than other system configurations.

Originally the Woodlands was designed with a direct/open loop system. That is one in which the domestic water flows directly through the collectors. Freeze protection in the warm gulf climate was accomplished by circulating (pumping) water through the collectors during freezes and opening a bypass valve during a power failure. This system design was re-evaluated once it was determined that the water quality was unacceptable and would foul the collectors rapidly. Various alternatives were considered including water treatment, but ultimately a closed system where the collector fluid is separated from the domestic water by a heat exchanger was selected.

Normally, anti-freezes are used in closed loop systems to prevent collector freeze-ups, but they generally require (by code) a double-walled heat exchanger to prevent contamination of the domestic water. These fluids are also generally more costly, more difficult to work with, and must be periodically replaced and/or maintained.

LEGEND

- GATE VALVE (OPEN FOR SOLAR)
- GATE VALVE (CLOSED FOR SOLAR)
- CHECK VALVE
- WYE STRAINER
- THERMOMETER
- TEST PLUG
- REDUCER
- F.M. FLOW METER
- PUMP
- CONTROL SENSOR
- UNION
- BALANCING VALVE
- PRESSURE GAUGE
- MANUAL DRAIN / AIR VENT
- LOW LEVEL SWITCH (SEE ELECTRICAL/CONTROL: 4/3, 12/3)
- EXISTING WATER METER
- PRESSURE RELIEF VALVE

NOTES

1. HEAVY LINES REPRESENT NEW WORK. LIGHT LINES REPRESENT EXISTING WORK.
2. EXISTING PIPE IS GALV. STEEL. NEW PIPE IS TYPE L COPPER.
3. INSULATE ALL NEW PIPE.
4. ALL EXTERIOR PIPE INSULATION SHALL BE PROTECTED FROM EXPOSURE TO SUNLIGHT W/ FLASHING OR ALUMINUM PIPE JACKETS.

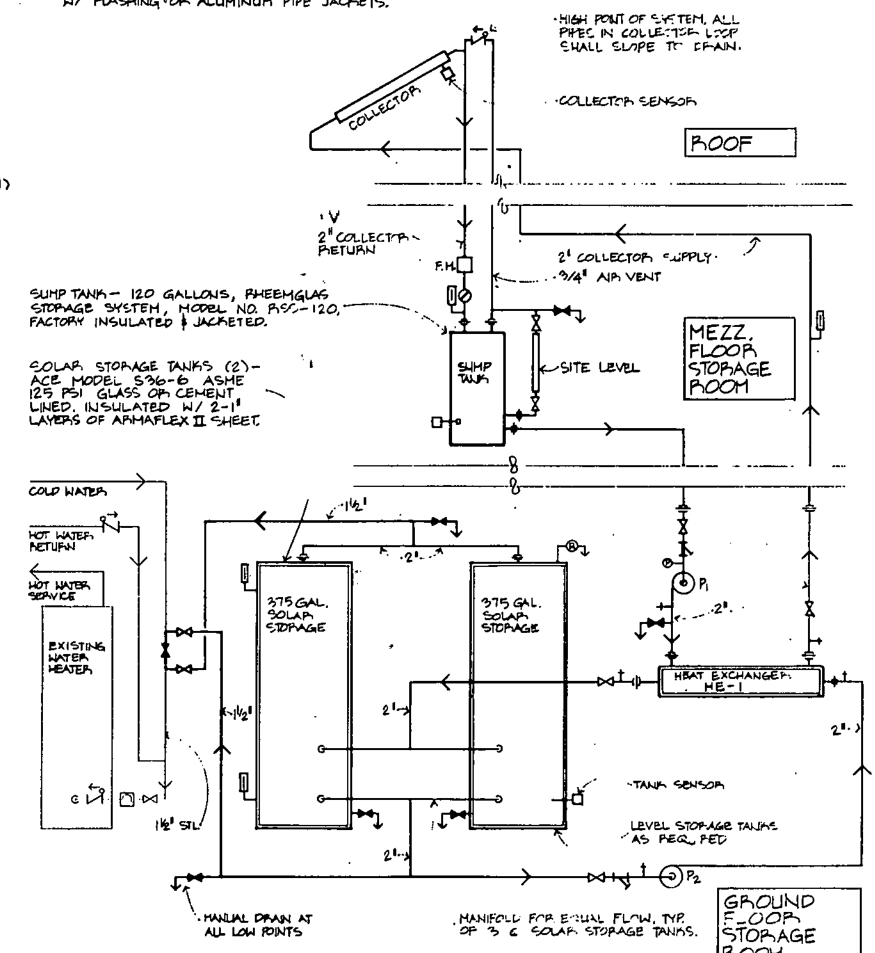
HEAT EXCHANGER SCHEDULE

	SHELL SIDE				TUBE SIDE				YOUNG RADIATOR CO. MODEL NO.
	GPM	°F IN	MAX. °F OUT	MAX ΔP	GPM	°F IN	MIN. °F OUT	MAX ΔP	
HE-1	22.5	105	90	3 FT	45	80	87.5	7 FT	F-606-EY-1P-B (BRASS BONNET)

NOTES
1. TOTAL FOULING FACTOR .003

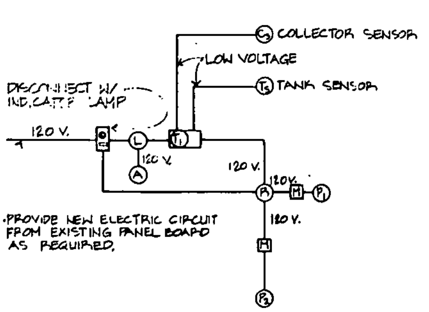
PUMP SCHEDULE

PUMP	GPM	HD.FT.	MOTOR RPM	HP	V	Φ	BELL & GOSSETT MODEL NO.
P_1	22½	25	1750	1/3	115	1	SERIES 60, 1½" AA
P_2	45	11	1750	1/4	115	1	SAME B (BRONZE)



11/3 SOLAR SYSTEM SCHEMATIC, MECHANICAL SCHEDULES

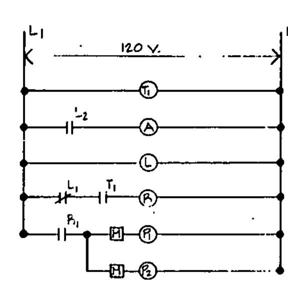
NO SCALE



12/3 ELECTRICAL DIAGRAM

NO SCALE

- (T) DIFFERENTIAL TEMPERATURE CONTROLLER
- (A) ALARM BELL – 120V. – 4" DIA., EDWARDS, OR EQUAL.
- (L) LEVEL CONTROL COMPLETE W/ FROBE ASSEMBLY – ONE MAKE, ONE BREAK, MANUAL RESET – McDONNEL #9C2-M.
- (R) RELAY – 120V. COIL – 2 N.O. CONTACTS NEMA 1 ENCLOSURE.
- (P) PUMP
- (M) MANUAL MOTOR STARTER W/ OVERLOAD PROTECTION. ARROW-HART RL-11 OR GE CR-101



4/3 CONTROL DIAGRAM

NO SCALE

If the collector array is designed to drain and its contents can collect in a sump tank during non-collection hours, plain water can be used, increasing the thermal transfer capabilities and allowing for a more efficient and less costly single-walled heat exchanger. This was the system chosen for The Woodlands.

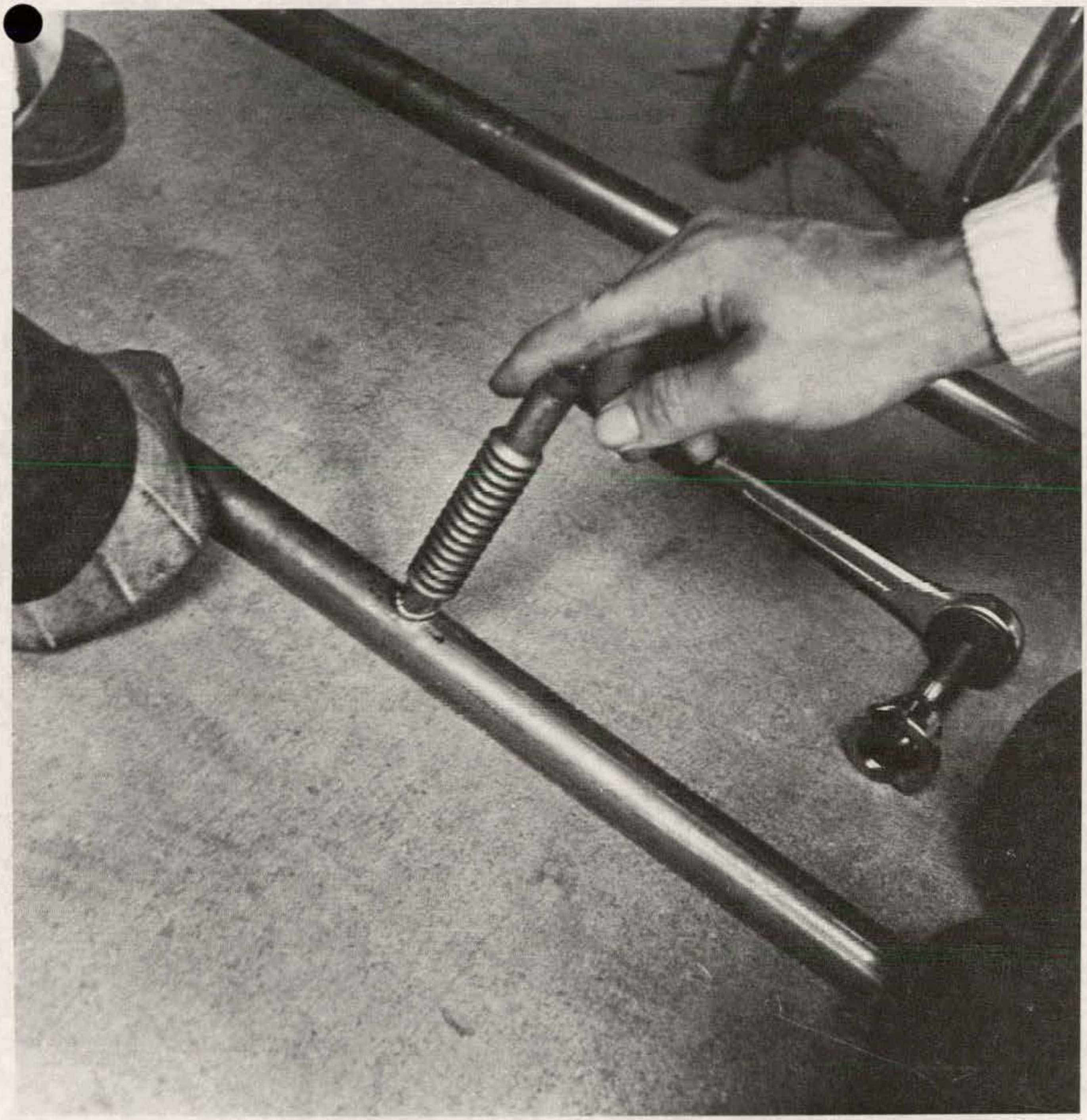
No mechanical or electrical controls are used for freeze protection, eliminating potential failures and maintenance requirements. Freezes coupled with power failures and/or accidental turning off of key components do not endanger the system. The problems associated with anti-freezes—e.g., cost, ease of handling, poor thermal transfer qualities, increased viscosity, potential damage to other building materials (some re-act to roofing materials), potential toxicity and required maintenance—are eliminated. Simplicity of the system, especially in the controls, is a major advantage of this system and its long-term acceptability.

The major disadvantage to this type of drain-back solar system design is the extra pump requirement to push the water from the sump tank level to the top of the collectors. Unlike a "full" system where the pump requirements only need to overcome friction, the potential requirement in this system is much greater. To minimize this additional static load on the pump the difference in sump tank level and the top of the collector should be minimized while still allowing for complete draining of the collectors and all plumbing exposed to freezing conditions. In several instances at The Woodlands Solar Project, the sump tank was located at the second floor level to minimize this requirement.

Other Innovative or Successful Design Details

Manifolds. Prefabricated manifolds utilizing Hydroflex flexible bronze tubing welded into tees pulled from the headers (no fittings) and Swagelok quick connectors for ultimate connection to the collectors, were chosen by the contractor. Pulling tees from the header saved considerable time in cutting pipe and welding in the fitting, and saved the fittings themselves. The use of flexible bronze tubing allowed for construction irregularities and ultimate expansion and contraction of the system. Quick connectors provided rapid installation of the manifolds minimizing labor on the roof. No flame (torch) was required on the roof—an important consideration with dry shakes.

Instrumentation. Extensive use of test plugs, a minimum of 10 on each system, has allowed for complete system analysis and de-bugging. In the future these temperature and pressure test points will help in maintenance and trouble-shooting. Thermo wells for accurate temperature readings combined with flow sensing elements are permanently installed and can be used with portable meters for accurate determination of instantaneous performance. As simple and inexpensive as these provisions are, it is surprising that most solar systems do not include them.



Fabrication of manifolds using T-puller and flex pipe.

Prefabricated manifolds.

Typical installation of prefabricated manifolds.

Detail of collector connection before insulating and flashing.

Construction Management on Solar Installation*

Although the trade skills required to install solar systems are generally common, the process is not second nature to most tradesmen and the potential for mistakes and lost time is great. Most contractors are faced with putting together a package using products and construction sequences with which they are not totally familiar. Considerably more supervision is required and additional time must be spent locating materials not yet common in the light commercial/ residential construction industry. Construction mistakes that require reworking of major components often involving several trades are not uncommon. Careful review of the contract documents, plans and specifications is necessary throughout the job. Realizing these costs and/or potential problems, contractors' bids are often above engineers' estimates on solar projects.

Construction management techniques are particularly successful in mitigating the high cost and potential problems associated with solar projects. Major cost items such as collectors can be prepurchased by the owner allowing for competitive purchasing and reduced contractor overhead. Additional specialty components and long-lead items can also be owner-purchased. Contract packages broken down by trade can be bid separately allowing the construction manager to discuss design details with each trade contractor reducing the fear factor and allowing for constructive criticism. During construction the owner is continually represented and the work monitored. Problems are caught early, saving time, money and potential litigation.

The benefits to construction management were enhanced at The Woodlands Solar Project where the construction manager was also responsible for the design. Intimate understanding of the design and its rationale assured the maximum quality control and allowed for the most flexibility. The design was continually reviewed and revised to reflect new ideas and lessons learned. This was especially appropriate in this case where 12 separate systems have been installed and four more are on the way. The general contractor, Solar Systems of America, was the low bidder in all three phases. Their experience and long-term interest in solar utilization helped toward the project's success. Contractor cooperation and flexibility were key factors in the successful implementation.

*Construction management has been developed as an alternative to the traditional building process. Construction management seeks to save the owner time and cost primarily through better activity coordination and project management. The construction manager is retained by the owner to manage his project from start to finish. As his agent, the construction manager implements the project for him. Often the same subcontractors who would build it in the traditional contract structure do so under construction management, only they are dealt with directly—not through a general contractor. The owner pays a fee for the CM services, which is offset by his not having to pay a general contractor's overhead and profit.

Cost Control

Cost overruns and wide variations in bids are common in solar installations. The design/construction management firm, Interactive Resources, Inc., was particularly successful in controlling costs of this project in light of required design changes that increased the system cost, i.e., conversion from an open to a closed loop. System costs have been experienced twice as high in projects designed by the same firm, but where construction management was not provided. During the first round of bidding in this project, the price range was substantial, the lowest bidder being less than half of the highest (over a dozen bids were reeeived).

Construction costs for the first phase (12 guest clusters) were seven per cent over the budget. Prices for the subsequent two phases came in under the budget such that the total project came within the total budget. Unfortunately, due to the two separate DOE grants, the money could not be intermixed. Costs for the Inn (Phase I and II) exceeded the DOE budget by approximately $3,000 or a little over one per cent. Subsequently the atypical guest lodge, clustar BB, was dropped from the project reducing the costs approximately $12,000. Costs for the aquatic center (Phase III) have come in below the budget.

The Woodlands Solar Project

COST SUMMARY

Inn			
Design/testing		$27,100	
Construction management		18,000	
Owner purchases			
Collectors	$78,611		
Other	17,049		
		95,660	
Contracted material and labor			
Phase I (12 clusters)	$71,710		
Phase II (inn and guest house)	40,561		
		112,271	
			$253,031
Aquatic Center			
Design/testing		$13,700	
Construction management		6,600	
Owner purchases			
Collectors	$22,697		
Other	3,700		
		26,397	
Contracted material and labor		30,298	
			76,995
Total			$330,026
Budget*			$354,039

*Note: One cluster (BB) was eliminated and the collector area on the Aquati⁻ Center reduced for a total reduction in collector area of 8.5 per cent (which is the primary reason for the costs below budget).

Testing

A comprehensive acceptance test and on-site collector performance test was developed and is being implemented by the designer/construction management firm who anticipate a growing demand by owners and engineers for independent system/component performance certification as the solar industry develops. Generally, existing testing programs fall into two categories: (1.) next to nothing, and (2.) sophisticated data acquisition systems costing as much as the solar systems themselves. The need for an inexpensive yet accurate and comprehensive testing program is desirable not only from the standpoint of assuring the owner of anticipated performance but also for use in start-up, balancing and debugging and in the future for maintenance and servicing.

The instrumentation system developed for the Woodlands Solar Project was designed to allow for a broad range of tests with a minimum of permanently installed equipment. Expensive components such as the pyranometer and integrator used for solar measurements and the manometer used for flow measurements were portable and used to test all the systems. A test unit provided by the controller manufacturer was used by the construction manager (responsible for all testing) to check and calibrate the automatic control systems.

Pyranometer measures sunlight falling on collector, used to determine performance.

Thermal Analysis

Computer Simulation

Solar performance calculations were performed and economic optimizations made using FCHART, a computer simulation program developed by the University of Wisconsin. Of course, any computer program is only as good as the information fed into it.

Graphic Summary

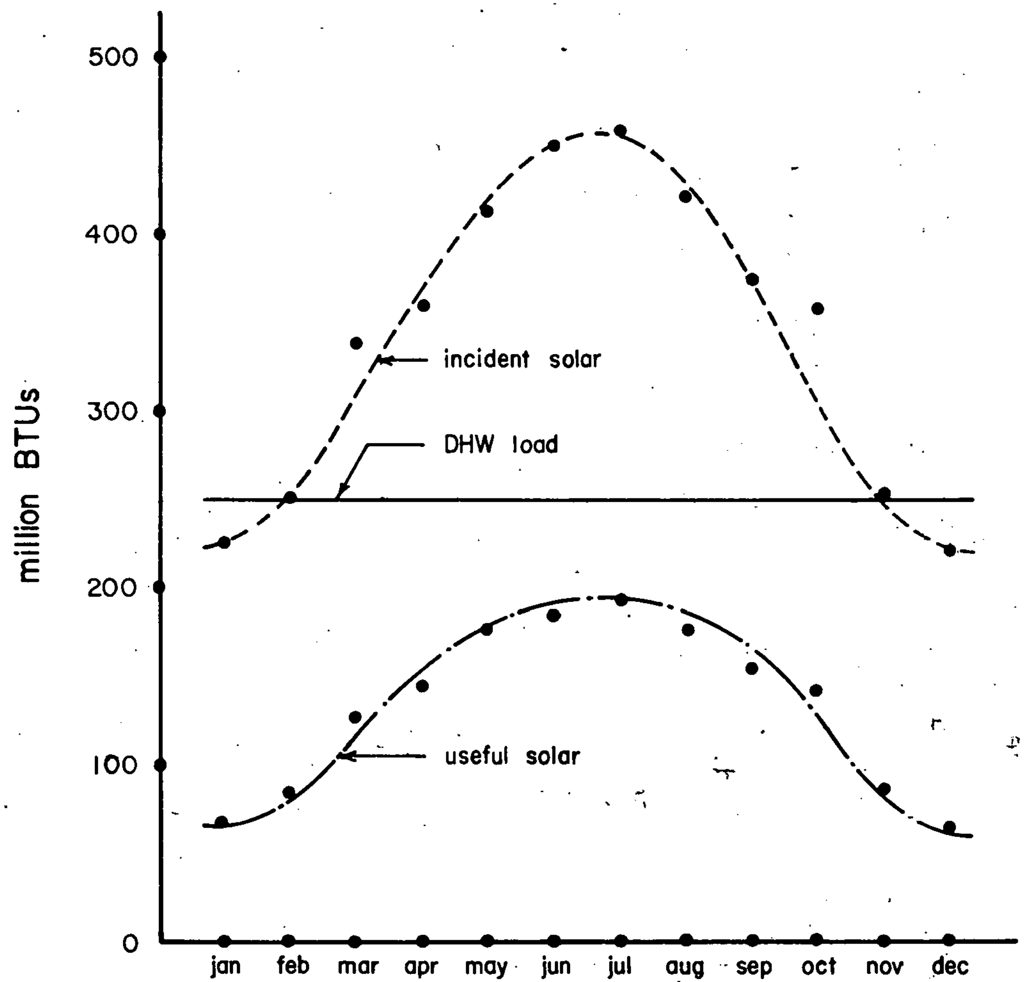
Figures 4, 5 and 6 illustrate the relationships between load (heat required), incident solar (energy received by the collector), and useful solar (solar energy delivered to load—accounting for system efficiency).

Water Meters Installed

One variable that is extremely important is the load; in this case, the amount of hot water used and at what temperature. Estimates were made on the number and duration of showers for the guest housing, aquatic center and health studio, and for the number of dishwasher cycles in the conference center and wharf. Water meters were subsequently installed at four locations to confirm the estimates. Following the collection of metered data, the size and/or configuration of several systems were adjusted accordingly. No additional computer runs were made. The total collector area was reduced 8.5 per cent and a corresponding reduction in output is expected.

Originally the conference center solar system was to be tied into the wharf—an adjacent building—but water meters were installed in the design development phase and consumption measured in the conference center was considerably higher than the anticipated combined load. Therefore, adding the load created by the wharf was not justified due to the budgetary limitations on the solar system's size. No more energy would be produced or saved by the solar system if the wharf's load were added since the system would only be providing a small percentage of the conference center's requirements.

In the aquatic center, domestic hot water consumption was so far below original estimates that 600 square feet (half the collector area) was cut—still allowing for considerable growth in consumption.



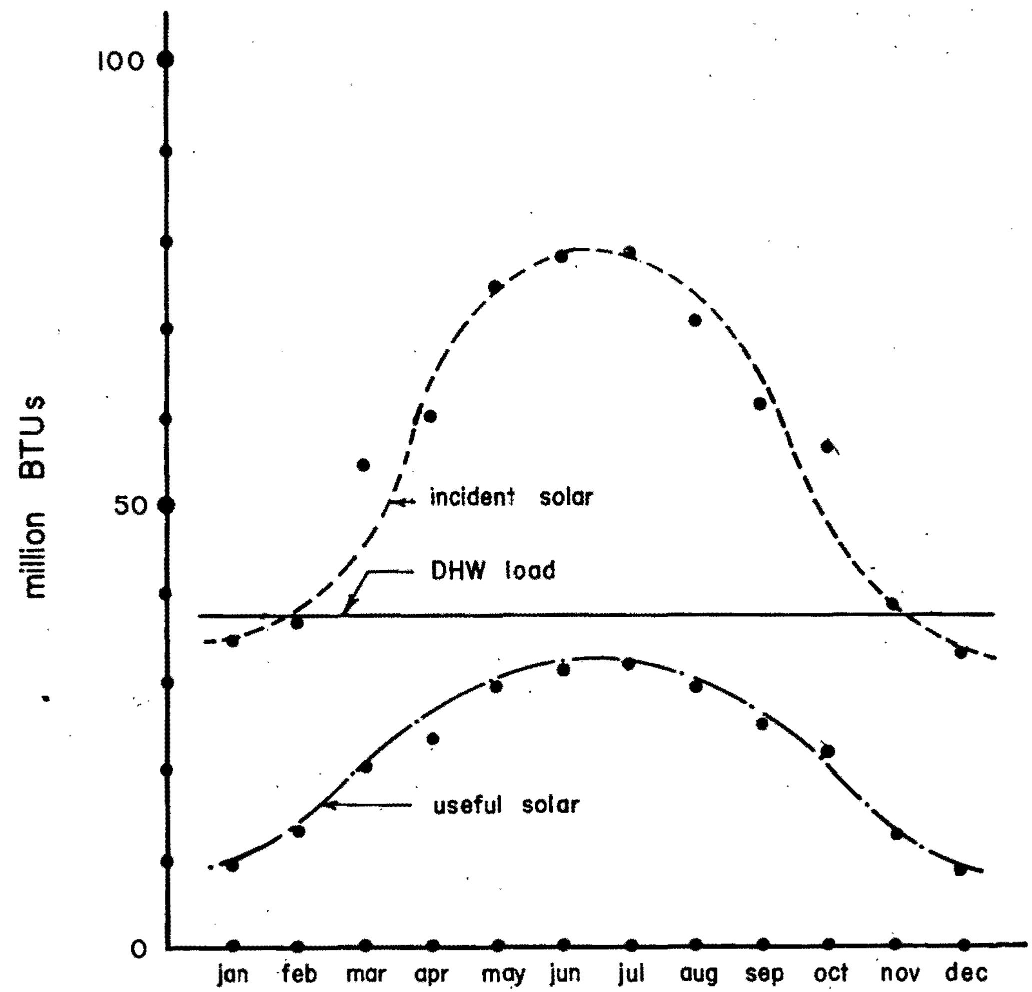
SUMMARY OF SYSTEM AND THERMAL PERFORMANCE

System
- 7,140 sq. ft. glazed flat plate collector

Annual Performance
- hot water demand: 4.8×10^6 gallons at 140°F
- load (assuming 66°F incoming water): $2,977.5 \times 10^6$ BTU
- incident solar: $4,154.5 \times 10^6$ BTU
- useful solar: $1,606.2 \times 10^6$ BTU (annual collector efficiency: 38.7%)
- percent solar: 53.9%

the woodlands inn — solar heating proposal

fig. 4 — guest housing, conference center, & wharf- solar DHW heating



SUMMARY OF SYSTEM AND THERMAL PERFORMANCE

System
- 1,200 sq. ft. glazed flat plat collectors

Annual Performance
- hot water demand: 730,000 gallons at 140°F
- load (assuming 66°F incoming water): 451.3×10^6 BTU
- incident solar: 679.5×10^6 BTU
- useful solar: 257.3×10^6 BTU (annual collector efficiency: 37.9%)
- percent solar: 57%

the woodlands inn — solar heating proposal

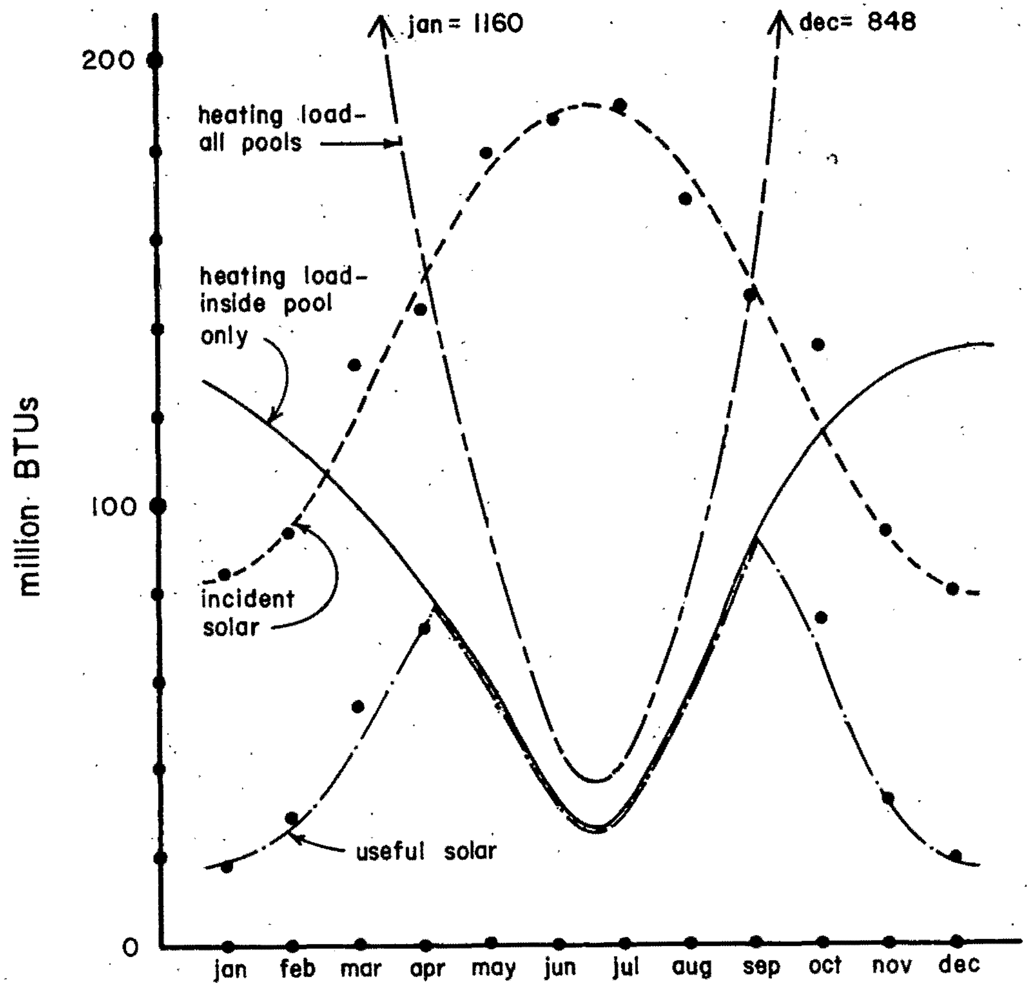
fig. 5 aquatic center- solar domestic hot water heating

Size and Performance Reductions

With the elimination of 360 square feet of collector on Cluster BB and the reduction of 600 square feet of collector on the aquatic center (domestic hot water system), the total collector area was reduced 8.5 per cent and a corresponding reduction in output is expected. No additional computer runs were made.

Aquatic Center

Figure 6 illustrates the aquatic center indoor pool heating and includes a graph of the total load for all the pools, indoor and out. Unlike the indoor pool, which has a year 'round load due to the air conditioning, the outdoor pools have a seasonal load. Unfortunately, the incident solar drops to 29,047 BTU/sq.ft. in January from a high of 65,637 BTU/sq.ft. in July and the collector efficiency drops to a low of 22.2 per cent from a high of 63.5 per cent in August. Therefore, very little solar energy is available in the winter (6,440 BTU/sq.ft. in January) to offset the enormous heat requirements. Over six times this energy is available in the summer when the load is also considerably lower. Adding collector area would supply a greater per cent of the load in the winter, but would not be cost effective considering that it would not be used for most of the year. Already, the system's capacity is greater than the load for four to five months per year.



SUMMARY OF SYSTEM AND THERMAL PERFORMANCE

System

2,880 sq. ft. unglazed collector

Annual Performance

load (gas meter x 0.7):
$1,145.6 \times 10^6$ BTU

incident solar: $1,630.9 \times 10^6$ BTU

useful solar: 641.4×10^6 BTU
(annual collector efficiency: 50.1%)

percent solar: 56% (indoor pool)

fig. 6 aquatic center- solar pool heating

Architecture Engineering Construction Management Energy Management
Point Richmond San Francisco Petaluma Houston

Interactive Resources, Inc.

P.O. Box 7358 (2220 Buckthorne Place, Suite 120) The Woodlands, Texas 77380 713/367-7727

THE WOODLANDS SOLAR PROJECT
Status Report: May 15, 1979
Economic Considerations

Collector Unit Output

Although during recent tests I have experienced outputs close to twice as much, original engineering estimates indicate an average system performance of 685 BTU's per square foot of collector area per day. This estimate was based on a computer analysis using independent collector test data and long term weather information.

Solar System Output

Once completed the solar water heating systems will comprise of close to 10,000 square feet of collector area producing and/or saving an estimated 2,500 million BTU's per year.

Utility Savings

Generally electricity is used for water heating at the Inn. The solar heating systems will save the equivalent of approximately 735,300 kilowatt hours (KWH) per year. At various meters, the Inn is currently paying between 3 and 4.6 cents per KWH. Assuming 4¢/KWH, the first year's savings will be $29,400. In addition the owner will qualify for the newly enacted 10% federal solar tax credit amounting to $35,400, for a combined savings of $64,800 in the first year.

Fixed Cost

Once a solar system is installed it fixes the cost of the energy it produces. In other words, the cost of solar heating will not rise as the cost of electricity and the fuels used to produce it escalate (skyrocket). Assuming that the value of the money used to install the solar heating system is 10% per year then the cost of solar heating in this case is $35,400* for the equivalent of 735,300 KWH. The fixed cost of solar produced energy is therefore 4.8¢ per KWH equivalent. Solar utilization is a hedge against utility price inflation.

* Due to a government grant the owners cost would actually be one-half or $17,700 per year and 2.4¢ per KWH equivalent.

In addition to reduce the owner's tax liability the solar system can be depreciated and the interest (if financed) is tax deductible.

EQUIVALENT GAS

When high concentration energy sources are used to heat water (under 180°F) less of those sources are available for industry and transportation. Solar utilization will reduce the demand for and shortages of gas and oil and/or will reduce our import requirements. Assuming a 40% conversion and delivery efficiency, the Woodlands Solar Project will save the equivalent of approximately 62,500 gallons of gasoline per year. In addition, solar installations stimulate the local economy by providing construction, manufacturing and related jobs and minimize economically devastating importation of foreign oil.

Stanford University Central Food Services Building
Solar Space and Domestic Hot Water Heating System

Charles L. Beavers, AIA, Interactive Resources, Inc.

KEY WORD ABSTRACT

Application: Domestic hot water and space heating
System type: Active hydronic
Collector type: Flat plate, liquid, single-glazed
Collector manufacturer: Solar Energy Products, Inc.
Collector area: 840 square feet (aperture)
Storage capacity: 1,550 gallons, steel tanks
Building load: 203 x 10^6 BTU/year
BTU's produced: 142 x 10^6 BTU/year
Building owner: The Leland Stanford Junior University
Construction and Engineering Office
The Old Pavilion
Stanford, CA 94305
Solar system designer: Interactive Resources, Inc.
117 Park Place
Point Richmond, CA 94801
Contractor: Redwood Mechanical
1590 Tacoma Way
Redwood City, CA 94063

INTRODUCTION

The Stanford University Central Food Services Building is located on the Stanford campus approximately 30 miles south of San Francisco. It is a single-story building with flat roofs. It is used for food preparation and storage and includes administrative offices.

The building was previously fed by a steam main from Stanford's central steam plant located about two miles away. Over the years, significant deterioration occurred in this line, resulting in wasteful heat losses. Stanford terminated steam service to the building and replaced it with a solar system and gas-fired backup.

A cost-sharing proposal for construction of the solar system was submitted to ERDA (now DOE) under Cycle 2 of the Commercial Solar Heating and Cooling Demonstration Program in November, 1976. Funding was awarded in 1977. Construction bids were received in March, 1978, construction began in June, 1978, and was completed in April, 1979.

PROJECT STATUS

At the time of this writing, July, 1979, the solar system is operating smoothly. In June, a rust problem (not related to the solar system) in the backup storage tank forced the shutdown of the backup water heating system. Building operations have not been interrupted, however, because the solar system and good California weather have provided 100 per cent of the heating requirements.

ENERGY CONSERVATION

Stanford University has been and continues to be concerned with energy conservation. In the Central Food Services Building, the most significant of their accomplishments has been the complete abandonment of 87 per cent of the original heating system. Three of the original four heating coils have been shut down leaving only the offices in the administration wing to be heated. All storage and work areas are simply no longer heated. Instead of only turning down the thermostats at night, the heating system is turned off 13 to 14 hours a day. Furthermore, no heat is used on weekends. These measures save 73 per cent of the fuel used if heated for 24 hours, seven days a week.

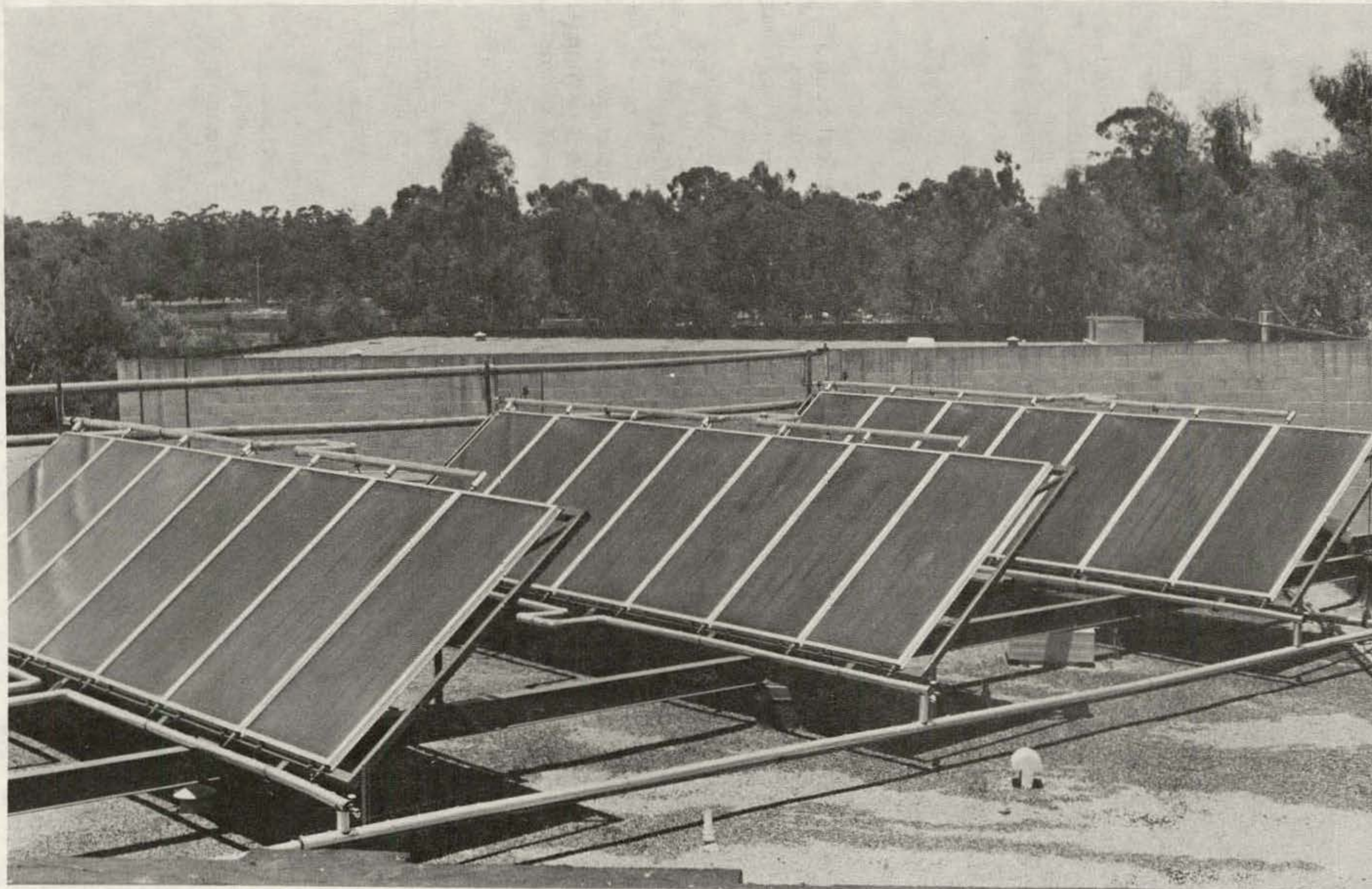
The majority of hot water consumed in the building is used in the late afternoon to wash down the meat processing area. A pressurized spray system was installed that reduced hot water consumption from nine to 4.5 gpm.

Energy conservation-motivated changes have resulted in at least a 60 per cent heat use reduction for the Central Food Services Building at Stanford, and possibly up to an 80 to 90 per cent reduction.

> RECOMMENDATION: Large amounts of energy can be saved by the simplest measures. The savings from turning off equipment when unnecessary (sometimes completely), reducing use temperatures, and reducing hot water usage, can overshadow the savings from even the best solar system.

SOLAR SYSTEM DESIGN PHILOSOPHY

The solar system was primarily designed as a hot water heating system with space heating as a secondary function because hot water (used mainly to wash down the meat processing area) comprises an estimated 72 per cent of the building solar load. In the schematic design phase, an open loop system was planned using potable water as both the transfer fluid and storage medium. This prevented the necessity of heat exchangers which might have reduced efficiencies and increased costs.



Collectors viewed from the east.

In a response to their experiences with previous installations, designed by themselves and by others, the solar system designer, Interactive Resources, Inc., completely reevaluated the system design during the final design stages, primarily in an effort to arrive at a totally satisfactory freeze protection system. Even though the mild climate of northern California offered only an average of three or four freezes a year, none of the freeze protection systems for open loop systems (pump cycling, thermic drains, drain out and drain back systems using electronic valves, and combinations) were determined to be satisfactory.

An antifreeze system was then considered, but offered several disadvantages including the necessity (by code) for a double-wall heat exchanger (additional cost and reduced efficiency) and the additional maintenance costs required for replacing and closely monitoring the transfer fluid.

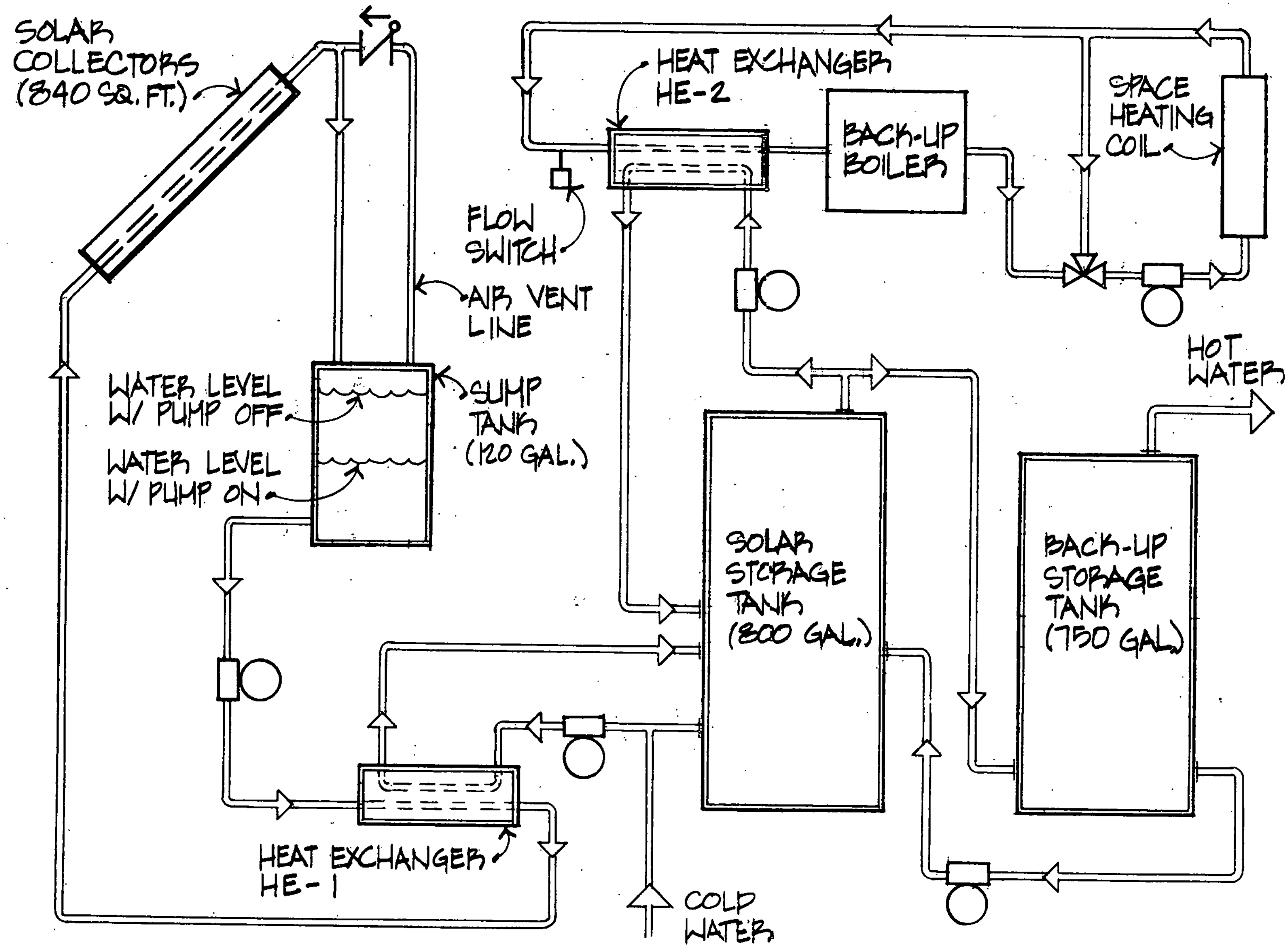
In an effort to combine the advantages but eliminate the difficulties of these systems, a completely revised collector loop design was developed which combined the dependability of gravity drain-back freeze protection with low maintenance, minimal costs and, of prime importance, simplicity.

This closed-loop drain-back system uses no mechanical or electrical controls for freeze protection, eliminating potential failures and maintenance requirements. Freezes coupled with power failures and/or accidental turning off of key components do not endanger the system. The problems associated with antifreezes (e.g., cost, ease of handling, poor thermal transfer qualities, increased viscosity, potential damage to other building materials [some react to roofing materials], potential toxicity and required maintenance) are eliminated. If the collector array is designed to drain and its contents can be stored in a sump tank during non-collection hours, plain water can be used, increasing the thermal transfer capabilities and allowing for a more efficient and less costly single-wall heat exchanger. Simplicity of the system, especially in the controls, is a major advantage of this system.

> RECOMMENDATION: The closed-loop drain-back system offers many advantages over other domestic hot water collector loops, including the dependability of gravity drain-back freeze protection, low maintenance, minimal costs and simplicity.

SOLAR SYSTEM OPERATION DESCRIPTION

The solar heating system on the Central Food Services Building provides space heating and domestic hot water heating. Of the total energy supplied by the system, approximately two-thirds is used to offset the year round domestic hot water heating load, while approximately one-third is used to offset the seasonal space heating load.



SOLAR SYSTEM SCHEMATIC

Collector-to-Heat Exchanger Loop

Energy in the form of heat is transferred from the solar collectors to a heat exchanger HE-1 via a closed drain-back loop. This loop includes the solar collectors, the sump tank (120 gallons), a pump, and heat exchanger HE-1. This loop uses normal untreated tap water as the transfer medium.

The collector-to-heat exchanger loop is a closed loop containing water and air. Neither water nor air enters or exits the loop unless done so manually. With the pump off, the water level is flush with the top of the sump tank. All the piping above this level contains air.

When the pump is turned on, water is circulated from the sump tank, through the heat exchanger, up through the collectors and back to the sump tank. Air is forced from the collectors into the sump tank. The water level in the sump tank will drop to around 1/4 full.

When the pump is turned off, the weight of the water creates a suction at the top of the system. The check valve to the air vent line opens allowing air to flow from the sump tank through the air vent displacing water in the collectors and manifolds, thereby draining all the water from the collectors into the sump tank.

Heat Exchanger-to-Solar Storage Tank Loop

The solar storage tank contains potable water and feeds the supply side of the backup hot water storage tank. Water in this tank is circulated through the heat exchanger HE-1 and returned to the tank. This completes the transfer of heat from the collectors to the solar storage tank.

The pump in the collector-to-heat exchanger loop and the pump in the heat exchanger-to-solar storage tank loop operate together. They are controlled by a differential thermostat. This controller compares the temperature in the collector with the temperature at the bottom of the solar storage tank. When the collector is 20°F warmer than the solar storage tank, the pumps are turned on. When the collector temperature drops to only 3°F warmer than the solar storage tank, the pumps are turned off.

Solar Space Heating Loop

Solar-heated water is stored in the solar storage tank. Water in this tank is used to pre-heat the return water in the backup space heating loop. This is done through heat exchanger HE-2.

When a differential thermostat senses that the temperature in the solar storage tank is 8^{O}F warmer than the return water in the backup space heating loop, the solar space heating loop pump is turned on. The pump is interlocked with a flow switch in the backup heating loop. The pump will come on only if there is flow in the backup heating loop. When the storage tank temperature is only 3^{O}F warmer than the return water in the backup heating loop, the pump is turned off. A gas-fired boiler adds heat to the backup loop, if required, but only after passing through the solar heat exchanger.

Tank-to-Tank Loop

The solar storage tank serves as a pre-heat tank to the backup hot water storage tank. When hot water is used in the building, it is drawn from the top of the backup hot water storage tank. Makeup water to this tank comes from the solar storage tank. Cold water makeup enters at the bottom of the solar storage tank. Backup heat is supplied to the backup storage tank by a gas-fired boiler, if required.

When the solar storage tank temperature is greater than the temperature in the backup storage tank, water is exchanged between tanks via the tank-to-tank loop. This increases the solar storage capacity during periods of high solar input and/or low loads.

When a differential thermostat senses that the solar storage tank is 10^{O}F warmer than the backup hot water storage tank, the tank-to-tank loop pump is turned on. When the solar storage tank is only 3^{O}F warmer, the pump is turned off.

RECOMMENDATION: By installing a loop between the solar storage tank and the backup storage tank, the backup tank can be used for solar storage (when the solar tank temperature exceeds the backup tank set temperature) during periods of high solar input and/or low loads, when storage is most needed.

THERMAL ANALYSIS

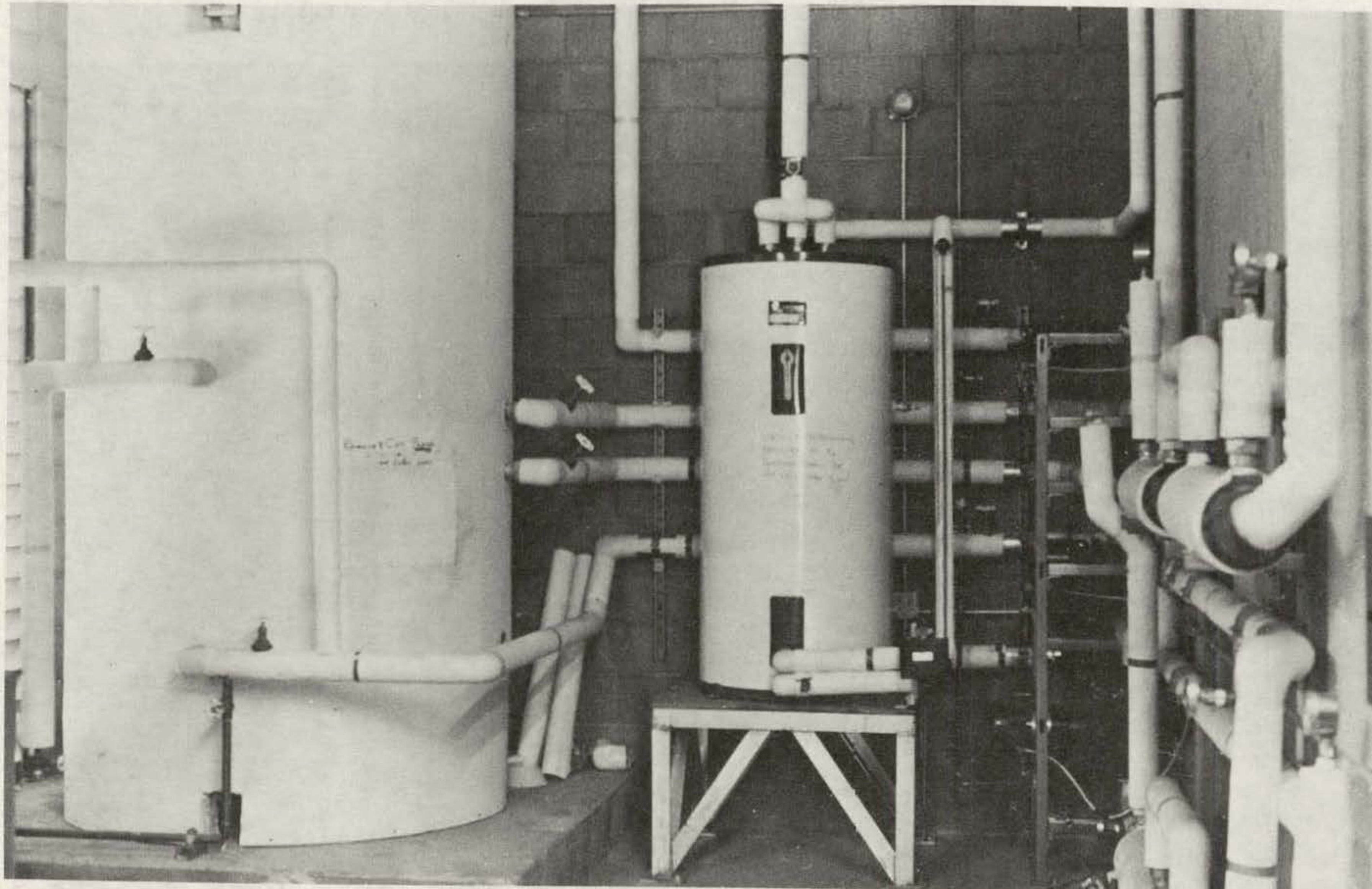
Solar performance calculations were done using a computer design program (FCHART) developed by the University of Wisconsin. FCHART is an interactive computer program used to calculate the thermal performance of solar space heating and domestic hot water heating systems. A general design procedure was developed at the University of Wisconsin from information gained from a simulation model capable of estimating the long-term thermal performance of solar heating systems based on the system design parameters, heating loads and weather. Solar and weather data for the calculations were taken from the California Solar Data Manual written by the Energy and Environmental Division of the Lawrence Berkeley Laboratory.

Stanford University
Central Food Services Building

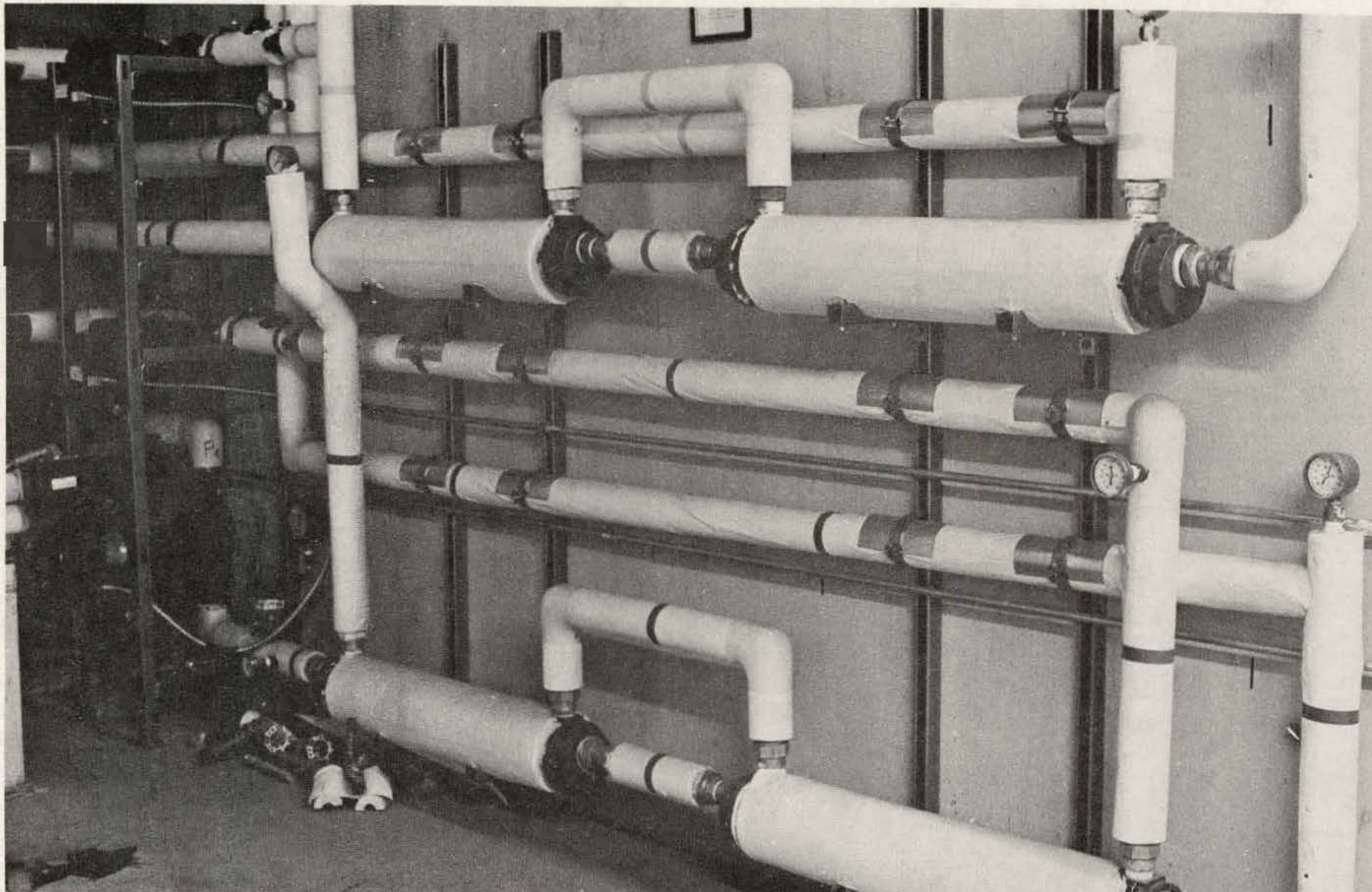
SOLAR SYSTEM THERMAL PERFORMANCE

	Space Heating Load (BTU x 10^6)	Water Heating Load (BTU x 10^6)	Total Load (BTU x 10^6)	Solar Used (BTU x 10^6)	Percentage Solar
January	10.4	11.5	21.9	9.5	43.3
February	7.8	13.6	21.4	12.1	56.4
March	6.7	13.6	20.3	14.1	69.5
April	4.6	15.4	20.0	15.7	78.4
May	3.0	13.8	16.8	15.0	89.2
June	1.1	11.9	13.0	12.5	95.9
July*	.7	9.8	10.5	10.5	100.0
August*	.6	9.1	9.7	9.7	100.0
September*	1.0	4.8	5.8	5.8	100.0
October	2.8	11.6	14.4	12.3	85.2
November	6.2	12.7	18.9	10.3	54.6
December	9.6	12.0	21.6	9.8	45.4
Total	54.5	139.8	194.3	137.3	70.6

*Summer break occurs in July, August and September.



Mechanical room: Solar storage tank on left, sump tank in center, heat exchangers on right.



Mechanical rcom: Heat exchangers mounted on wall.

COLLECTOR SELECTION

The FCHART computer program allows the introduction of specific collector performance parameters (Y-intercept and slope based on independent tests) into the calculations. This performance analysis was coupled with the FCHART economic analysis to determine the best BTU-per-dollar value among selected collectors. Using collector test data together with vendor quotes, many different collectors were analyzed to compare their performance and price on this specific project with its particular weather, load and temperature characteristics. Some costs, such as varying costs for supports and manifolding, had to be estimated, and some judgments, such as quality of construction and durability, were a necessary part of the evaluation not shown in the FCHART analysis. These judgments, it turned out, reinforced the results of the computer simulation which showed the Solar Energy Products, Inc., collector producing the most BTU's per dollar.

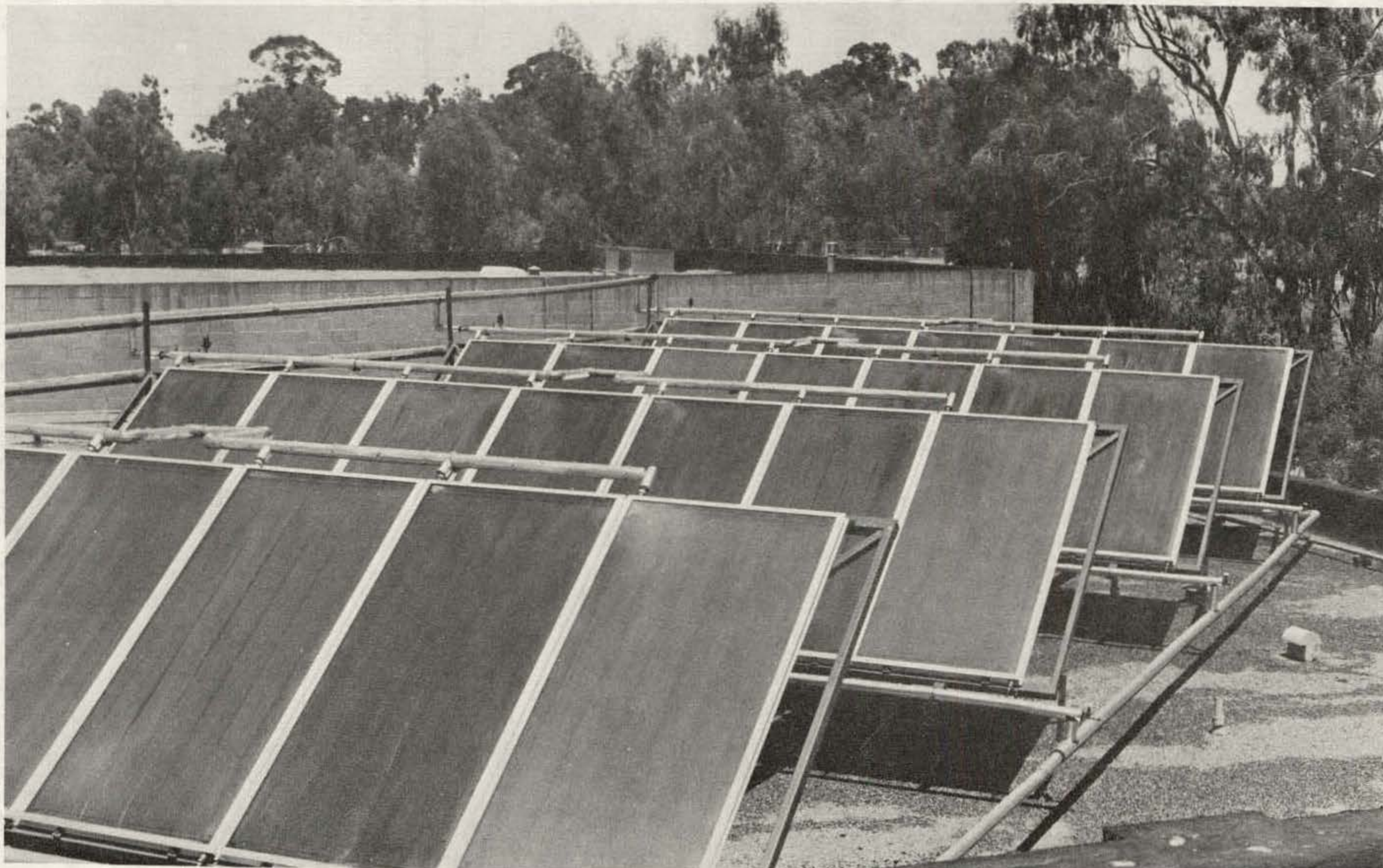
The solar system was, therefore, designed around this collector. Several other collectors were also acceptable and actually bid (including Revere and Sunworks) but the system was installed by the low bidder with Solar Energy Products, Inc., collectors.

RECOMMENDATION: The FCHART computer program can be helpful not only in performing thermal and economic analyses, but also in making a cost-benefit analysis of alternate collectors on a system-by-system basis.

STRUCTURAL SUPPORT PROBLEMS

During detailed design, it was realized that the collectors were to be mounted on a lightweight panelized roof system (common on warehouse and storage structures such as this) which was not intended to accept additional roof loads. A structural analysis confirmed that the addition of solar collectors on the roof would require considerably more structural work (and cost) than had originally been anticipated or budgeted. After considering numerous alternate schemes, a structural system was finally adopted which consisted of structural steel beams and trusses spanning over 20 feet and supported over the column points of the building below.

RECOMMENDATION: A preliminary structural analysis should be routinely included in solar feasibility studies so the impact of structural requirements can be anticipated and budgeted early when the feasibility and economics of the project are determined.



Four banks of solar collectors.

BIDDING

Bids were solicited from six contractors, all of whom were experienced commercial mechanical contractors (union labor) who had done work for Stanford University before. The bids were very close with the three lowest within only a few hundred dollars of each other.

The solar space heating loop was included in the bid as a deductive alternate. In this way, the scope and cost of the project could be lowered without substantially reducing the energy saving benefits. Stanford decided, however, that the dollar savings were not substantial enough to justify dropping the space heating portion of the system and construction proceeded on the entire system as designed.

COSTS

Construction costs were originally budgeted during preliminary design at $44,250. During the final design stages, however, it became apparent that this budget could not be achieved. Some of the reasons were:

1. Substantial additional costs were required on the collector support structure because the existing roof was not able to withstand the extra load of the collectors.

2. A higher quality system was constructed than had originally been budgeted. There were additional costs in converting from an open- to a closed-loop drain-back system (primarily in the extra cost of a sump tank, heat exchanger and pump) and higher quality components were used throughout.

3. Contractor overhead and profits were higher than anticipated.

ECONOMICS

With an initial investment of $71,304 (the costs of design and construction), and the present cost of natural gas at $0.25 per therm, inflated at 15 per cent each year (just a reference; your guess is as good as mine), the undiscounted fuel savings will equal the initial investment in 22 years.

The installation of a solar system fixes the cost of energy for years to come. If the system performs at its expected level (producing 1,373 usable therms per year and, at a 65 per cent natural gas efficiency, saving 2,112 therms per year) for 20 years, the equivalent cost of the solar system is $1.68 per therm saved. If the system should last 30 years, then the cost is $1.12 per therm, and at 40 years, $0.84 per therm.

By comparison, if natural gas inflates at 15 per cent a year, the 20 year average price would be $1.27 per therm. The 30 year average price would be $3.61 per therm.

Stanford University
Central Food Services Building

SUMMARY OF CONSTRUCTION BIDS

Contractor	Base Bid	Deductive Alternate For Space Heating Loop
A (Redwood Mechanical - contract winner)	$64,561	$(2,948)
B	64,600	(4,500)
C	64,900	(5,160)
D	69,686	(3,953)
E	74,500	(3,000)
F	78,240	(5,133)

Stanford University
Central Food Services Building

SOLAR SYSTEM PROJECT COST SUMMARY
(All costs include overhead and profit)

	Materials	Labor	
Collector support structure	$12,000	$ 2,168	
Collectors	13,841	572	
Collector manifold piping	160	1,024	
Storage tank (800 gallons)	3,500	1,680	
Storage tank insulation	200	500	
Sump tank (120 gallons)	634	650	
Pumps	1,175	850	
Heat exchangers	2,176	800	
Piping and valves	2,945	5,180	
Pipe insulation	1,000	4,760	
Controls	600	1,168	
Electrical	1,000	2,000	
Painting	1,000	1,258	
Testing and balancing		600	
Miscellaneous		1,120	
Subtotals	40,231	24,330	
Total base construction contract			$64,561
Plus changes during construction:			
Storage tank relocation		$ 997	
New collector loop pump (with new heaters and relays)		711	
Miscellaneous piping changes (pressure gauge, relief valves, etc.)		535	
			2,243
Total construction cost			$66,804
Design costs (not nearly enough)			4,500
Total design and construction costs			$71,304
Extra project costs:			
DOE reporting		$5,000	
Misc. printing and postage		277	
Stanford's staff costs for coordinating, reviewing and inspecting the project (not nearly enough)		3,000	
			8,277
Total project cost			$79,581

DEBUGGING THE HYDRONICS OF THE CLOSED, DRAIN-BACK COLLECTOR LOOP

The closed drain-back collector loop contains water and air. During non-collection hours, when the pump is off, the water in the collectors drains out and down into a sump tank located in the building. This means that when the pump comes on again, it must pump water to the top of the collectors, overcoming the force of gravity. This static head increases as the distance in height increases.

RECOMMENDATION: To minimize additional static load on the pump, the sump tank should be located to minimize the height difference between the sump tank water level and the top of the collectors while still allowing for complete draining of the collectors and all plumbing exposed to freezing conditions.

Once over the high point, water falling down the pipe creates a negative pressure at the top which sucks water coming up the pipe. The theoretical advantage of this "syphon return" over an "open drop" system is reduced pump head requirements. The pump need only be sized to overcome the static head at a very low flow. Once the "syphon return" has been established, the head loss against which the pump operates will only be flow friction losses.

The sizing of the collector loop pump was based on this concept as outlined in Bell & Gossett's Solar Design Manual. Unfortunately, this manual and the Stanford solar system both contained a basic flaw which precluded the successful execution of this concept.

Once a negative pressure is established at the top of the loop, air is sucked through the air vent line (which allows the collectors to drain when the pump is off) before water is syphoned up the pipe. A syphon return will never occur.

This problem became apparent on the Stanford solar system when it was found that the collector loop pump was delivering only half its design flow. A solenoid valve could have been installed in the air vent line to allow the syphon to occur, but this was rejected since one of the main reasons for going to this system in the first place was to eliminate the use of electronic or mechanical valves. (The system might not drain if the solenoid valve stuck in closed position.) It was necessary, therefore, to replace the original collector loop pump (1/2 HP) with a new 3/4 HP pump.

RECOMMENDATION: The pump in the closed-loop drain-back system must be sized to overcome static as well as dynamic head losses. A syphon return will not occur unless some method is employed to prevent the air vent from breaking the syphon (e.g., a solenoid valve in the air vent line).

With the new pump installed, it was then discovered that there was a negative pressure on the suction side of the pump. This causes the pump to cavitate and reduces its life expectancy. The problem was believed to be due to a combination of factors: (1.) The pump was only a few feet below the sump tank water level (which meant there wasn't much static head on this powerful pump to begin with); (2.) there were undersized fittings to the sump tank (a standard tank in a nonstandard use) which created extra flow resistance; (3.) a wye strainer before the pump which added resistance; and (4.) several 90° elbows were located in the line between the sump tank and the pump. This was a necessary result of the layout and also (as discovered in The Woodlands Solar Project being constructed at the same time) because the pump had to be mounted close to the floor with flow in the vertical direction.

RECOMMENDATION: The sump tank should be located high above the pump to put as much head as possible on the suction side of the pump.

RECOMMENDATION: The pump should be mounted with flow in the vertical direction to prevent air pockets from developing over night (out of the very aerated water) in the volute of the pump.

Instead of attempting to reduce the flow resistance between the sump tank and the pump, the whole closed drain-back loop was pressurized to put positive pressure on the suction side of the pump. A minimum (cold) pressure of 5 psi is maintained at the suction point of the pump.

This increased pressure meant the maximum (hot) pressure would come close to the set point (30 psi) of the relief valves located on each bank of collectors. The relief valves were, therefore, replaced with 70 psi valves.

MISTAKES AND OTHER THINGS WHICH SHOULD HAVE BEEN AVOIDED

Collector Sensor Not Properly Located

When the system design was changed from an open loop to a closed drain-back loop, the collector temperature sensor, instead of being relocated, was left in the collector manifold. In an open loop system this would have worked because water remains in all the piping overnight and the sensor, through syphoning and conduction, would have registered collector temperature rise in the morning. In the closed drain-back loop, with no water in the pipes in the morning, the manifold and the sensor were thermally isolated from the collector and early morning temperature rise could not be registered by the controller. A new sensor was, therefore, installed directly to the back of the collector absorber plate.

RECOMMENDATION: Carefully review drawings and specifications before construction, with special attention given to the side effects of design changes.

Storage Tank Foundation Revised

Drilled piers were originally designed to be dug in the mechanical room to resist earthquake loads of the vertically-mounted solar storage tank. Underground electrical ducting was discovered during construction passing directly through two of the piers. This could have been avoided by careful examination of the electrical as-built drawings. Even though the electrical ducts were empty (to be used for future expansion), the storage tank was relocated to take advantage of a better location (recently freed by the removal of some unused equipment) and the tank support redesigned (to avoid further surprises). The new design consisted of a heavy raised slab instead of piers to prevent overturning.

RECOMMENDATION: Carefully examine as-built drawings for potential conflicts on retrofit projects.

Sloping of the Collector Support Structure

The collector support structure was designed to slope with the roof. This allowed the collectors and piping to be mounted square with the support structure while still achieving the necessary slope for draining water out the collectors. Without realizing the intent of the design, the contractor installed the support structure level. This not only would have hampered drainage, but increased the height of the roof support stands at the low points of the roof. The extra height increased the moment loading (created by wind) on the supports. The roof support stands were not designed to take this extra load and the contractor, therefore, had to reinstall the collector support structure as designed. The steel did not have to be refabricated.

RECOMMENDATION: The contractors should not only understand the "what" of the design, but also the "why," so they can effectively judge the consequences of changes (initiated by themselves and others) and look for opportunities of improving the system and lowering costs.

Flow Switch Not Installed Properly

The flow switch (which signals the solar system when there is a space heating load) was improperly installed because the piping connection was too small, preventing the paddle (which extends into the flow pipe and is displaced by flow) from moving.

RECOMMENDATION: Carefully read manufacturer's installation instructions.

RECOMMENDATION: Carefully review drawings and specifications before construction, with special attention given to the side effects of design changes.

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RECOMMENDATION: Carefully examine as-built drawings for potential conflicts on retrofit projects.

Sloping of the Collector Support Structure

The collector support structure was designed to slope with the roof. This allowed the collectors and piping to be mounted square with the support structure while still achieving the necessary slope for draining water out the collectors. Without realizing the intent of the design, the contractor installed the support structure level. This not only would have hampered drainage, but increased the height of the roof support stands at the low points of the roof. The extra height increased the moment loading (created by wind) on the supports. The roof support stands were not designed to take this extra load and the contractor, therefore, had to reinstall the collector support structure as designed. The steel did not have to be refabricated.

RECOMMENDATION: The contractors should not only understand the "what" of the design, but also the "why," so they can effectively judge the consequences of changes (initiated by themselves and others) and look for opportunities of improving the system and lowering costs.

Flow Switch Not Installed Properly

The flow switch (which signals the solar system when there is a space heating load) was improperly installed because the piping connection was too small, preventing the paddle (which extends into the flow pipe and is displaced by flow) from moving.

RECOMMENDATION: Carefully read manufacturer's installation instructions.

Differential Thermostats Not Labeled Adequately

Three differential thermostats were used in the system, each with different set points. When they arrived at the site, they all looked the same, so the electrician installed them without regard to which controller went where, until small set point markings were found written inside the controller.

RECOMMENDATION: Set point markings should be boldly displayed on the outside of controllers.

Site Gauge Only Partially Effective

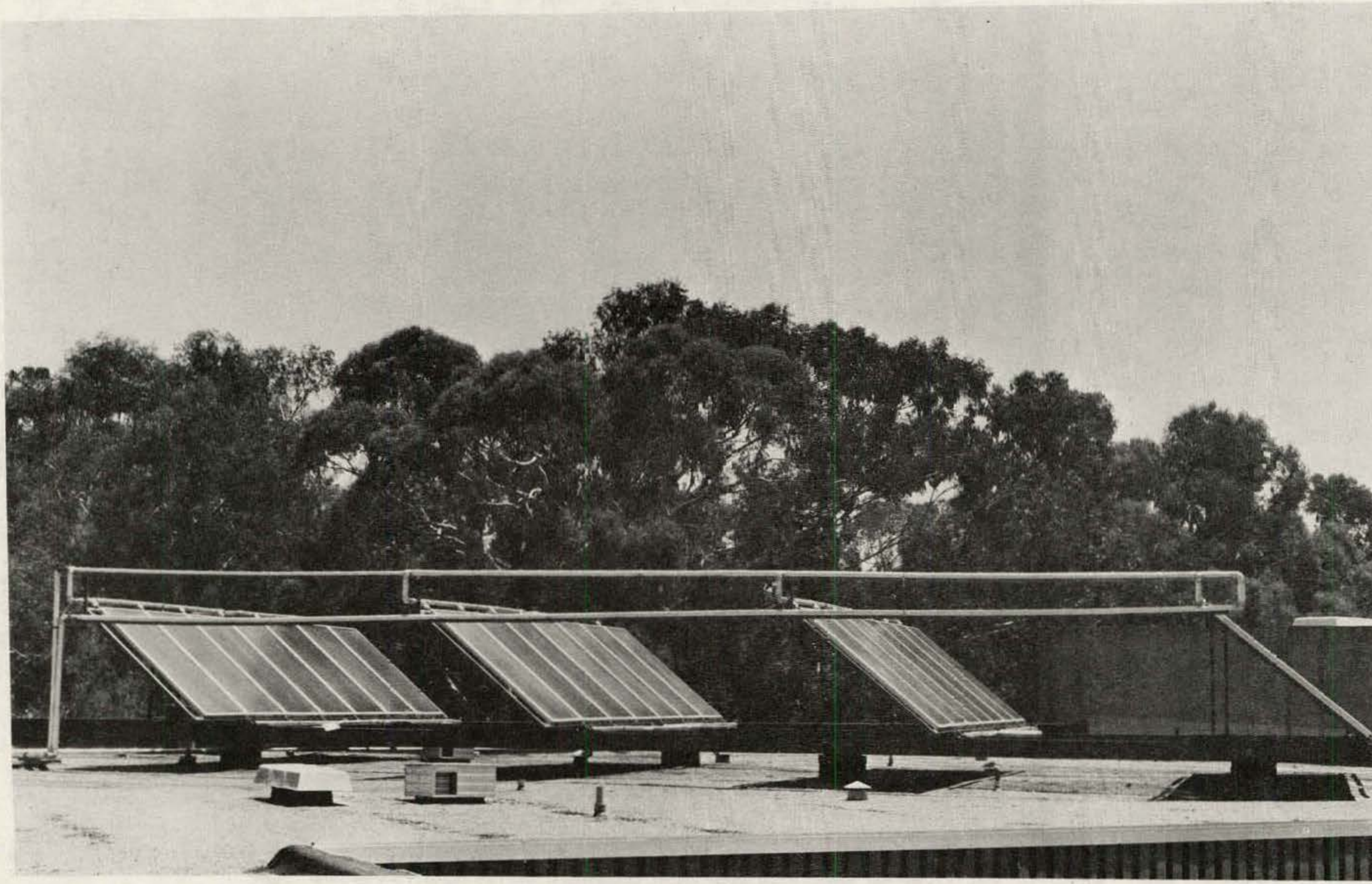
A site gauge was installed on the collector loop so the water level in the sump tank could be monitored. With no connections to the tank available, the site gauge was connected to the piping between the sump tank and the pump at the bottom and to the air vent line at the top. This prevents the site gauge from being used when the pump is on because, if valving to the site gauge is left open, the pump immediately sucks all the water down and out of the gauge, and when the pump first goes off, the air vent line sucks water up the site gauge. This configuration, though not desirable, was satisfactory in monitoring the water level, but only during static conditions.

RECOMMENDATION: A site gauge should be included in the collector loop to monitor water level. The gauge should preferably be connected directly to the top and bottom of the sump tank so the water level can be monitored during dynamic as well as static conditions.

Flying Pipes

The collector piping was designed to have only one high point from which water drains on both sides of the collector. This made the piping simpler and less expensive, eliminating the need for the air vent to go to each of the four collector bank high points. To do this, the return piping was run high in the air between the collector banks. Once installed, the pipes were considered unsightly by Stanford personnel. A price for lowering the pipes was quoted by the contractor ($1,935) but rejected by Stanford. Painting the jacketing a dark color is being considered as an inexpensive alternative.

RECOMMENDATION: Carefully review the visual impact of the system. A consensus of opinion may not always be possible, but visual considerations are sometimes as important as performance and other technical factors.



Collectors viewed from the west.

THE CHURCH OF THE VALLEY

A Case Study in the Architecture of Energy Conservation

by Wm. Stevens Taber, Jr.

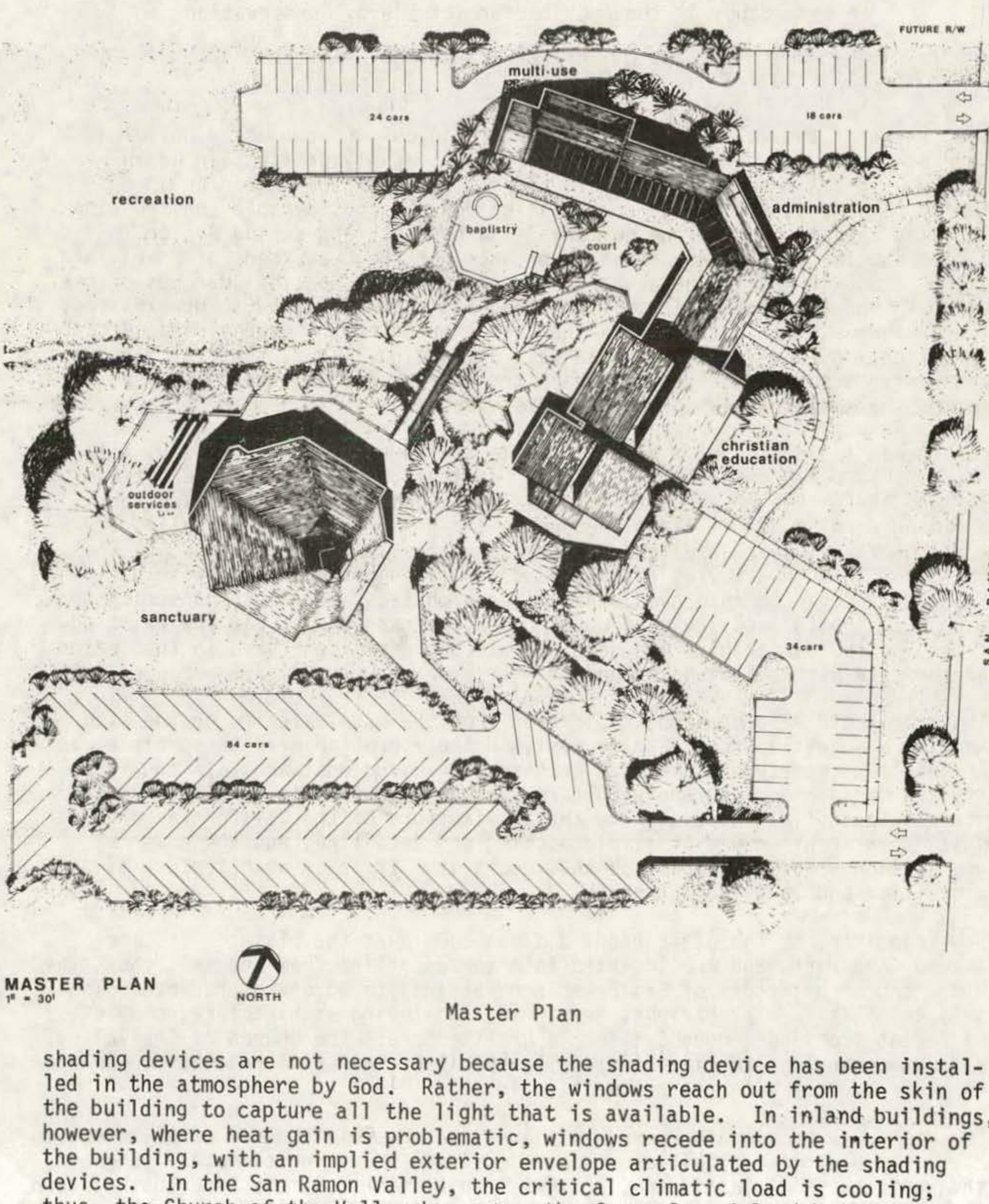
The Church of the Valley is a complex of religious and community buildings located 35 miles east of San Francisco in the rapidly growing San Ramon Valley. It was conceived by the founding members of the church as an opportunity to demonstrate energy conservation for the considerable construction activity taking place in the communities around it, and during design it became a solar energy demonstration project for the Department of Energy and a case study in energy conservation for the American Baptist Churches of the USA. In the latter capacity, it was required to be designed to use 75% less energy than similar buildings in the area, including the energy used in cooling, lighting, and ventilating, as well as heating. Thus, the design process began with detailed analyses of projected energy use, and these analyses informed the decision-making process throughout.

The church is located on a beautiful site in the heart of the valley, with an existing barn and several majestic old oak trees, and a wet weather stream through the middle of the site. Initially, two approaches to siting the building were studied: first, rendering the project into a wholistic, sculptural geometry, surrounded and supported by the site; second, grouping the buildings in such a way as to make outdoor places between them, with building and site integrated into each other. The architects saw the opportunity to make a delightful and inviting outdoor space around the stream and existing trees, so the master plan was developed to enclose a courtyard in the center of the site with buildings around it.

The architects also derived inspiration from the barn existing on the site. America was settled from east to west, in the migration over the prairie, and as American society and American architecture moved westward, all the frivolity and decadence of European culture were baked out of it, until it reached its quintessential expression in the architecture of the California barn. This is an architecture of simple massing and detailing, and the powerful expressiveness of the landscape that bears it. It is an architecture of asceticism and spiritual strength.

San Francisco, on the other hand, did not come over the plains: It came around Cape Horn, and was inserted into the coastline from the sea; thus, the Victorian architecture of San Francisco retains its European character almost intact. This is a gregarious, emotional, fun-loving architecture, completely different from indigenous California architecture. The Church of the Valley, although near San Francisco, is in the spirit of the California barn, seeking to be in harmony with the place it is in.

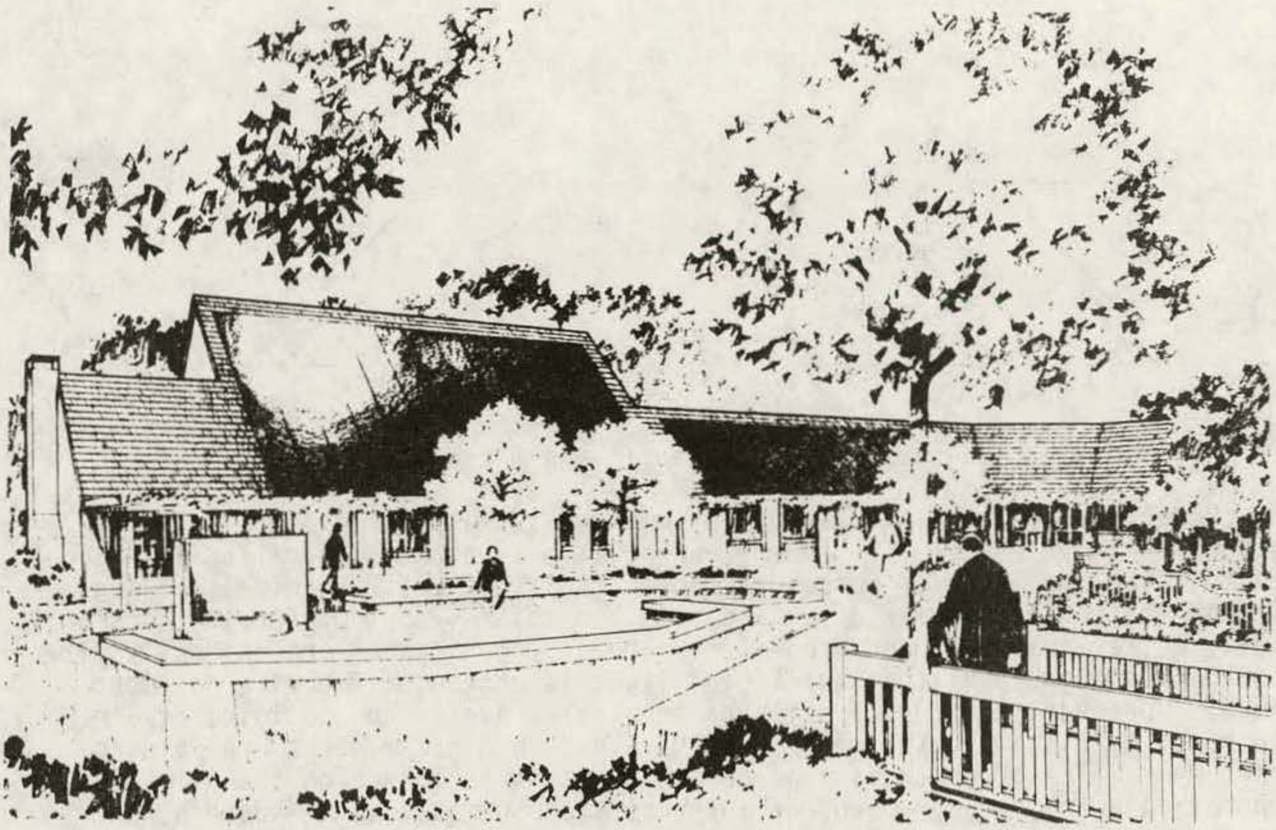
The Victorian houses also serve to illustrate the relationship of buildings to the sun. Victorian architecture has flourished in marine climates: England, the north coast of California, southwestern British Columbia, and southwestern Australia. In these climates, the summer sun is generally obscured by fog;



Master Plan

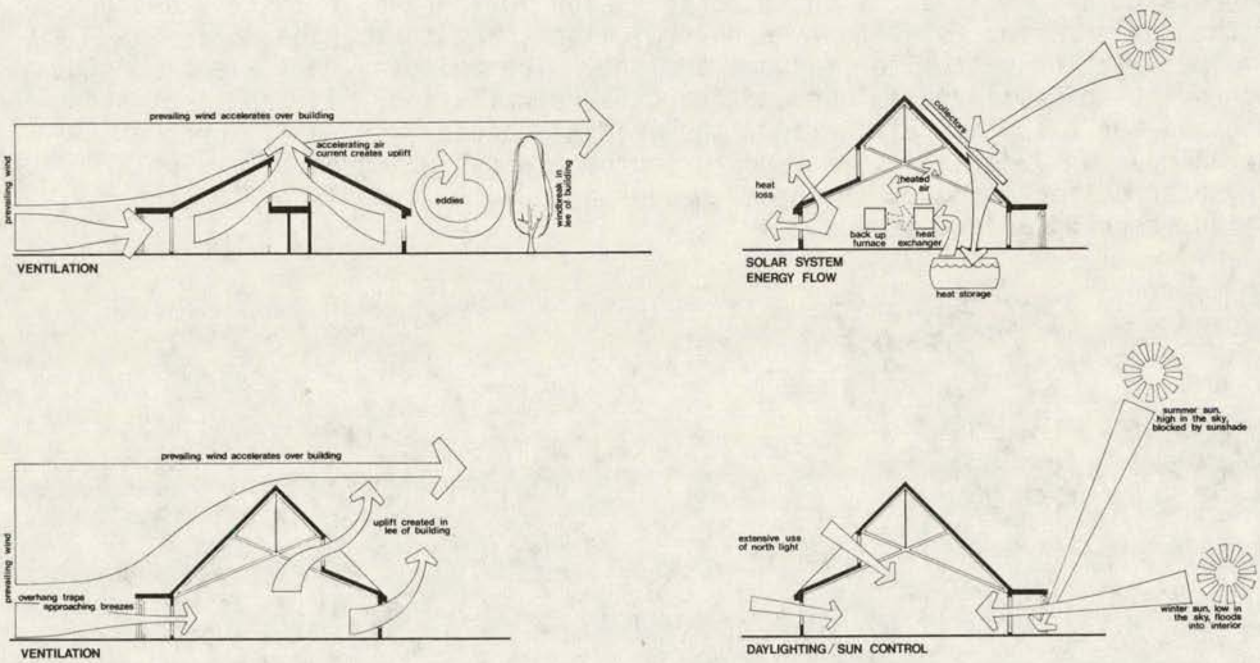
shading devices are not necessary because the shading device has been installed in the atmosphere by God. Rather, the windows reach out from the skin of the building to capture all the light that is available. In inland buildings, however, where heat gain is problematic, windows recede into the interior of the building, with an implied exterior envelope articulated by the shading devices. In the San Ramon Valley, the critical climatic load is cooling; thus, the Church of the Valley has taken the form of an inland building, with deep overhangs on the south-facing glass, and blank walls facing east and west.

These major issues were evident in the earliest design studies of the project: sun protection, natural lighting, simple massing and detailing, and siting for the creation of outdoor space. As the design developed, the energy conservation system was refined; it included provision for the solar system, design of the fenestration for effective natural light, and the design of a nighttime ventilation system for natural cooling. The building form was also studied for its effectiveness in promoting cross ventilation. In the final studies, all the essential elements of the initial concept were still present, including a well-defined courtyard for outdoor worship and baptisms, with the solar collector bank, which has become a powerful symbol for the congregation, serving as a backdrop.



Perspective of Outdoor Baptistry to Multi-Use Room
from creek looking past redwood

The design and procurement of the solar system was intended to minimize problems for a technically unsophisticated owner. It is a simple, hydronic, drain-down system with high quality components and limited maintenance requirements. Procurement was done by means of a performance specification, which clearly fixes responsibility for the ultimate performance of the system with the design-build contractor, rather than limiting his responsibility to workmanship and material. This also encouraged him to exercise his design ingenuity in matters of cost control, which is the contractor's primary area of expertise.



Energy Systems: Natural and Mechanical

The project is now completed and occupied, and is fulfilling people's expectations on many levels. The energy conservation system is operating as anticipated, with the interior spaces remaining cool (without mechanical cooling) through the hottest summer days, and with the solar system performing substantially better than had been projected. The interior spaces are naturally lit to a high enough level that artificial light is unnecessary during daylight hours. Moreover, the congregation has coalesced during the building of its new home; morale among the members is very high and new members are joining every week. The project has also become a potent influence on the community, generating a tremendous amount of interest among neighbors, newspapers, and church groups; already several more such projects are beginning in the area, and similarly minded congregations from around the country are visiting and asking advice.

Lastly, the project has been a tremendous learning experience and a great satisfaction for the designers and builders involved, who have struggled with unfamiliar problems throughout the process, and have experienced all the aspirations and joys of the congregation members themselves. It has been a demonstration not only of energy conservation in architecture, but also of its human content, that part of the building process which makes architecture so much a living art.

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ROUTE 1 BOX 156 O
MELROSE FLORIDA
32666

NORMAN G. BYAR
FINK & ASSOC.
1701 ARCH ST. P
PHILADELPHIA PA
19103

ERNEST CACCAMO
COOPER CITY BUILDING DEPT
11610 STONEBRIDGE PARKWAY O
COOPER CITY FLORIDA
33328

FREDERICK G CADE
CITY OF OCEAN CITY
821 CENTRAL AVENUE P
OCEAN CITY NJ
08226

RAY CALIBERTE
GATEWAY ELECTRIC
328 WILLOW AVE. P
LONG BRAN NJ
07740

GEORGE J. CALIVA
PENN STATE UNIV.
602 E. THIRD ST. P
WEATHERLY PA
18255

DENNIS CAMPBELL
HOME FEDERAL SAVINGS & LOAN
701 BROADWAY L
SAN DIEGO CA
92101

MICHAEL J. CAMPO
TRINITY COLLEGE
1704 BOULEVARD P
W. HARTFORD CT
06107

JOHN CAMPOS
MONTEBELLO UNIFIED SCHOOL DIST
123 S MONTEBELLO BLVD L
MONTEBELLO CA
90640

FRANK CANDELARIO
TSI INC
3204 PRODUCTION AVE L
OCEANSIDE CA
92054

CELESTE CANTU
IMPERIAL VALLEY HOUSING AUTHOR
1401 "D" STREET L
BRAWLEY CA
92227

JAMES V. CAPIZZI
MIDDLESEX COUNTY VOC TECH HIGH
112 RUES LANE
EAST BRUNSWICK NJ P
08857

JOHN CAPONE
J. CAPONE CONSTRUCTION CO. INC
175 EAST MITCHELL AVE P
CHESHIRE CT
06416

JOHN B. CARLOCK
MUELLER ASSOCIATES INC.
1900 SULPHUR SPR. RD. P
BALTIMORE MD.
21227

JOHN H CARLSON
GOVERNOR'S OFFICE OF ENERGY R
7703 N LAMAR BLVD O
SUITE 502
AUSTIN TEXAS 78752

R. WILLIAMS CARLSON
ROEBLING CONSTRUCTION
P.O. BOX 37 P
ROEBLING NJ
08554

H. MAURICE CARLSTON
101 ALUMNI HALL OF ENGR.
LAFAYETTE 21 P
EASTON PA
18042

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VALENCIA COMMUNITY COLLEGE
BOX 3028 G
ORLANDO FLORIDA
32802

TERRANCE M. CARNEY
TVA SOLAR APPLICATIONS BRANCH
240 CSTZ-C P
CHATTANOOGA TN
37401

STEVE CARCLAN
GREENHOUSE SALES & IN
107 WESTWOOD CIRCLE P
RCSLYN HTS NY
11577

JOSEPH L CARROLL
CITY OF LONG BEACH
333 W OCEAN BLVD L
LONG BEACH CA
90802

DAVID E. CARTE
NAVAL SURFACE WEAPONS CENTER
CODE W-41 P
DAHLGREN VA
22448

MRS J W CARTER JR
222 ROBINHOOD
SAN ANTONIO, TEXAS
78209

BERNARD B CASH
CITY OF LOS ANGELES
ROOM 800;CITY HALL EAST L
200N MAIN ST.
LOS ANGELES CA 90012

JOSEPH A CASTELLANO
STANFORD RESOURCES INC
PO BOX 20324
7017 ELMSDALE DRIVE
SAN JOSE CA 95120

JOHN W. CATHEY
CARRIER CONSUMER CORP.
P.O. BOX 4808 P
SYRACUSE NY
13221

JAMES L. CAVENAUGH
PENNA DCA MUNICIPAL TRNG DIV
P.O. BOX 155 P
HARRISBURG PA
17120

BRUCE CAVIN
JOHN MILNER ASSOC.
309 N. MATLACK P
WEST CHESTER PA
19380

JOHN A. CAWLEY
UNITECH ENGINEERING INC.
P.O. BOX 130 P
PEABACK NJ
07977

RICHARD CHADWICK
3050 PENOBSEAT BLDG C
HURON CLENITON METROPOLITAN AV
DETROIT,MI
48226

C W CHAING
S D SCHOOL OF MINES & TECH
500 E ST JOE ST D
RAPID CITY, SD
57701

STEVE CHAMBERLIN
CAMPHILL SPECIAL SCHOOL
RD#1 P
GLENMOORE PA
19343

JA CHUCK CHAMBLESS
ENERGY MGMT SYSTEMS INC
603 SKI LODGE DRIVE C
MONTGOMERY ALABAMA
36117

JOHN R CHAMBLESS JR
CHAMBLESS KILLINGSWORTH ASSOC
5720 CARMICHAEL RD C
MONTGOMERY AL
36117

SUPAT CHANDRAMAS
329 NORTH NEW HAMPSHIRE #2
LOS ANGELES CA L
90004

HAN CHANG
ARGONNE NATIONAL LABORATORY
ROOM F316 L
BUILDING 362
ARGONNE IL
60439

KWEI KWANG CHANG
UNIVERSITY OF CENTRAL FLORIDA
331 PALMETTO C
OVIEDO FL
32765

MANOHAR LAL CHAUHAN
STATE OF CALIF DEPT OF WATER
P O BOX 388 L
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95802

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SOUTHERN UNIVERSITY
P O BOX 9785 L
BATON ROUGE LA
70813

PING CHENG
DEPT OF MECHANICAL ENGR
UNIVERSITY OF HAWAII L
HONOLULU, HI
96822

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4200 LIVINGSTONE DRIVE
YORK PA P
17402

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MADISON HEIGHTS,MI
48071

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SOUTHERN PACIFIC GAS CO
8210 S FLOWER ST L
LOS ANGELES, CA
90017

ALFONSO CHIRIBOGA
SAN DIEGO CITY SCHOOLS
4100 NORMAL ST, ANNEX 2 RM 107
SAN DIEGO CA
92103

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E E CHOAT
UNION CARBIDE CORP NUCLEAR DIV
P O BOX Y BLDG 9733-1 O
OAKRIDGE IN
37830

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ARGORRE,IL
60439

RICHARD CHORBA
GAMBLE-MUKHERJI & ASSOC.
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CLARKS SUMMIT PA
18411

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CALIFORNIA STATE UNIVERSITY
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90802

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19453

MR WILLIAM E CHRISTILLES
3534 ROCK CREEK RUN
SAN ANTONIO, TX
78230

JOHN C. CHRISTOPHER
CONTEMPORARY SYSTEM INC.
ROUTE 12 P
WALPOLE NH
03608

NIKKI CHUK
US DOE CHICAGO OPS
9800 S CASS AVE D
JOLIET,IL
60435

LARRY CINAT
27760 E LARKMOOR DR
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48076

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48226

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JOHN P. CLARK CO. INC
139 E. GLENSIDE AVE
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P
19038

STANLEY D CLARK II
CLAREMONT TENNIS CLUB
1777 PADUA AVE
P O BOX 848
CLAREMONT CA
L
91711

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CLAREMONT TENNIS CLUB
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RESEARCH DIVISION
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15129

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91711

BARBARA CLARKE
REAL TECH. REALTORS
LANDMARK SQ
STAMFORD CT
P
06901

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WORCHESTER PLYTECHNIC INST.
WORCHESTER MA
P
01609

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59 E VAN BUREN, SUITE 2610
CHICAGO,IL
D
60605

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MIAMI DADE COMM COLLEGE
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MIAMI FL
O
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BRADENTON FL
O
33505

PHIL CLEVELAND
EASTERN MICHIGAN UNIV
PHYSICAL PLANT
YPSILANTI,MI
D
48197

R J CLOSE
WILSHIRE DIVERSIFIED INC
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PORTLAND ME
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04102

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HASSINGER SCHWAM ASSOC. INC.
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P
19117

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ARGONNE,IL
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60439

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CAMPHILL VILLAGE USA INC
COPAKE NY P
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ARVIDA CORP
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FT LAUDERDALE,FL
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IRVINE CA L
92715

LEONARD COLTON
COLTON SOLAR
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LAKE ARROWHEAD,CA
92352

GERALD W COMPTON
ENVIRONMENTAL DESIGNS
200 PIER AVE #9 L
HERMOSA BEACH CA
90254

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ABS PROGRAM-CARNEGIE
MELLON UNIV. P
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TYLER,TX
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INTERLOCAL COMMUNITY ACT PROG
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EDMUND SCIENTIFIC CO.
101 E. GLOUCESTER PIKE P
BARRINGTON NJ
08007

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COOPERSON BRECK ASSOC
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MONTCHAHIN DE
19710

JUDY CORBETT
WESTERN SUN
C/O SOLAR CAL 921 10TH ST L
SACRAMENTO CA
95814

CHARLES CORCORAN
NORWESCAD INC.
PROSPECT ST. P
PHILLIPSBURG NJ
05865

JONATHAN B COSTA
THECREM CORP.
697 E BROKAW RD. L
SAN JOSE CA
95112

BRUCE COSTANZO
BALCOM GENERAL CONSTRUCTION
339 EAST ST D
BUFFALO NY
14207

FREDERICK A. COSTELLO
FREDERICK A. COSTELLO INC.
12864 TEWKSBURY DR P
HERNDON VA
22070

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COUCHMAN PROJECT GROUP
999 E VALLEY BLVD APT 37 L
ALHAMBRA CA
91801

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HUMBER COLLEGE
56 QUEEN ELIZABETH BLVD D
TORONTO ONTARIO, CANADA
M821M1

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MAURICE COURLAND & SONS
2112 BROADWAY P
NEW YORK NY
10023

RAPHAEL H. COURLAND
MAURICE COURLAND & SONS
2112 BROADWAY P
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10023

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GLASTONBURY CT
06033

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CEDAR SPRINGS MI
49319

LEXIE K COXON
JORDAN COLLEGE
360 W PINE D
CEDAR SPRINGS MI
49319

MARVIN CRAMER
ESSEX CHEMICAL CORPORATION
1CROSSMAN RD,SOUTH G
SAYREVILLE NJ
08872

PETER M CREELMAN
ENVIRO-ENERGY SYSTEMS
2701 SW 27TH CT D
MIAMI, FL
33133

RANDOLPH R. CROXTON
CROXTON COLLABORATIVE ARCH.
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NEW YORK NY
10028

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TEMPLE UNIV. GEOGRAPHY DEPT.
BROOD AND COLUMBIA P
PHILADELPHIA PA
19122

JOSEPH CULLEN
CARNATION RESEARCH
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VAN NUYS CA 91412

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1332 BAXTER ST PO BOX 4587 O
CHARLOTTE,NC

JOSEPHINE A CUMMINGS
SOUTHERN CALIF GAS CO
P O BOX 3249 TERMINAL ANNEX L
LOS ANGELES CA
90051

H WILT CUNNINGHAM
GILBERT COMMONWEALTH
209 E WASHINGTON ST D
JACKSON, MI
49201

JOHN A CURRY
JOHN A CURRY & ASSOC,ARCH,INC
325 CRAWFORD STREET C
TERRE HAUTE IN
47807

ROB CUSCADEN
HOME IMPROVEMENT CONTRACTOR
300 W ADAMS D
CHICAGO IL
60606

ED D'ARCANGELIS
CONNECTICUT SOLAR COALITION
46 GLENDALE CIRCLE P
STAMFORD CT
06906

ERNEST DAESCHLER
COOPER CARRY & ASSOC
1819 PEACHTREE C
ATLANTA,GA
30309

CHARLES C DAHL
VENTURA COLLEGE
3613 WILLOWICK DRIVE L
VENTURA CA
93003

CONSTANTINE G DALLAS,AIA
1126 MORSE AVE
CHICAGO IL D
60626

P R DAMSHALA
410 WICK AVE,YSU
ESB #207 C
YOUNGSTOWN OH
44555

LEE ANNE DANIEL
TRIANGLE TECH
635 SMITHFIELD STREET P
PITTSBURGH PA
15222

DR DAUTOVICH
ONTARIO HYDRO
700 UNIVERSITY AVE H7-F2 D
TORONTO,ONTARIO,CANADA
M5G146

GERALD A DAVIDSON
GERALD DAVIDSON CONSTRUCTION
221 WOODWARD RD O
BIRMINGHAM,AL
35228

BRADLEY R. DAVIS
MEENAN OIL COMPANY INC.
LEVITTOWN PKWY P
LEVITTOWN PA
19059

FORREST DAVIS
85 GRATIST
MT CLEMENS MI D
48043

MR & MRS LEONARD EARL DAVIS
11130 BALLET DRIVE
SAN ANTONIO, TEXAS
78216

JOHN DAWSON
3335 GREENLEAF BLVD
SOLAR UNLIMITED D
KALAMAZOO MI
49008

DICK DE RUSHA
PERSONAL PROGRAMMING SERVICE
14600 GOLDENWEST ST #116 L
WESTMINSTER CA
92683

ROBERT DEBOARD,AIA
KIVETT & MYERS ARCH & ENGRS
6000 LAKE ELENOR DR SUITE 100C
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WHITMAN REQUARD & ASSOC.
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MARTIN MARIETTA AREOSPACE
423 FIRST ST C
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BEN DENGLER
32107 LINDERO CANYON SUITE 209
WESTLAKE VILLAGE CA
L
91361

JAMES M. DENNISON
AMERICAN SOLAR RESOURCES LTD.
29 CLOVER DR P
SMITHTOWN NY
11787

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ATA
424 E 4TH ST D
CINCINNATI, OH
45202

MICHAEL P. DEVER
MICHAEL DEVER HOME IMPR. CONST
8 STONE RIDGE ROAD P
THORNTON PA
19373

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SOLAR ENERGY RESEARCH INST
1536 COLE BLVD O
GOLDEN,CO
80401

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SARGENT & LUNDY ENGR
524 N SHERIDAN RD, #38 D
EVANSTON IL
60202

AZIZ DEHKAN
DEHKAN FARMS
132 NEWTON-SPARTA ROAD P
NEWTON NJ
07860

CHAS J DELANEY
4117 SW 20TH AVE
GAINESVILLE,FL O
32601

CHARLES DELISIO
ERWIN AND AKERS ARCHITECTS
712 BENEDUM-TREES BUILDING P
PITTSBURGH PA
15222

ALBERT M DENNIS
STATE OF CALIFORNIA
4186 LAIRD ROAD L
LOOMIS CA
95650

BILL DENNY
SOUTHERN SOLAR ENERGY CENTER
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ATLANTA,GA
30338

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DICKSON & ASSOC
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HUNTSVILLE,AL
35805

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HUGHES JR HIGH SCHOOL LAUSD
6620 BIRCHTON AVE L
CONCGC PARK CA
91307

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DELMARVA POWER & LIGHT CO
800 KING STR. PO BOX 231 P
WILMINGTON DE
19899

BERNARD DIFLOAE
300 CITY HALL DRIVE
BALLWIN MC D
63011

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NAT'L BUREAU OF STANDARDS
BLDG 225 ROOM A114 DOPL
WASHINGTON DC
20234

RONALD S DILKS
219 BROAD ST.
SWEDESBORC NJ P
08085

MICHAEL G. DILLING
SOLARCRETE CORP.
7505 SUSSEX DR. P
FLORENCE KY
41042

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DILLON INTERNATIONAL,INC
733 WEST MARKET ST D
AKRON OH
44303

NILES DINGMAN
COMMERCIAL AIR COND,CO
3915 WEST 73TH AVE D
WESTMINSTOR CO
80030

MILTON J. DINHOFFER
GREENHOUSE SALES & INSTIN. CO
107 WESTWOOD CIRCLE P
ROSLYN HTS NY
11577

PETER DISIMILE
AMERICAN ENERGY SYSTEMS
102-18 64 AVE. P
FOREST HILLS NY
11375

RALPH DITCH
ARGONNE NATIONAL LABORATORY
9700 S CASS AVE L
ARGONNE IL
60439

JOSHUA DIXON
200 W 90 ST
NYC NY P
10024

DAN DIXON
743 N. POTTSTOWN PIKE
LIONVILLE PA P
19353

JAMES DIXON
200 W. 90 ST.
NYC NY P
10024

STEVE DIXON
COMMUNITY ACTON COM OF PIKE CO
109 THIRD ST D
PIKETON OH
45661

JIM DODD
WYLE LABORATORIES
2361 JEFFERSON DAVIS HGWY L
ARLINGTON VA
22202

BILL DOLLARS
LENNOX INDUSTRIES,INC
1600 METRO DR C
CARROLLTON TX
75006

JOSEPH A. DOLLARTON
ALLSTATE ROOFING & SIDING CO.
1522 OLD YORK RD P
ABINGTON PA
19001

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40601

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737 WATCHUNG AVE.
PLAINFIELD NJ P
07060

D J DOMINIK
CUSTOM & SOLAR HOMES INC
234 ANITA PL L
SANTA FE NM
87501

VERONIKA W DOMINIK
COMMERCE & INDUSTRY DEPT
234 ANITA PL L
SANTA FE NM
87501

WILLIAM F. DONAVAN
DONAVAN P & H
194 GLENCOE RD. P
UPPER DARBY PA
19082

GEORGE T DONNELLY JR
20969 INDIAN
D
SOUTHFIELD MI
48034

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CHAFFEY COMMUNITY COLLEGE
5885 HAVEN AVE L
ALTA LOMA CA
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CHAMBERSBURG PA P
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TRUMBULL CO BD OF EDUCATION
140 FRANKLIN ST,SW D
WARREN, OH
44482

RALPH C DOWNING
EI DU PONT DE NEMOURS & CO
PETROCHEMICALS DEPT FREON PROD
WILMINGTON DE P
19898

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S I MORRIS ASSOC
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77027

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PHILA. PA P
19103

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LONG ISLAND HIGHTING
175 OLD COUNTRY RD P
HICKSVILLE NY
11801

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LYNN J DRURY AIA ARCH
413 SIXTH ST
MORGAN CITY,LA
70380

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12754

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ZIMMERMAN CONSTRUCTION CO.
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19422

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STRAUB,VANDINE,DZIURMAN
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MCLEAN VA D
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HOUSING DEV CORP OF LANCASTER
8 N QUEEN ST. SUITE 701 P
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17603

GREEN L ECHOLS
4937 W 5TH AVE
GARY IN D
46404

O W ECKARDT
13 TRAVIS RD
NATICK,MA C
01760

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WESTCHESTER COMMUNITY
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RH EDWARDS
NAT'L AERONAUTICS & SPACE ADMI
CODE L-G P
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M C NOTTINGHAM CO OF CALIF
890 S ARROYO PKWY L
P O BOX 7007
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D M S M
3250 WILSHIRE BLVD L
LOS ANGELES CA
90010

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TRI STATE G & T
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THORNTON,CO
80241

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W R FRIZZELL ARCHITECTS INC
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WINTER PARK,FL O
32789

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M8Z1M1

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UNIVERSITY OF TOLEDO
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TOLEDO OH
43606

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AIR FORCE ROCKET PROPULSION LB
AFRP4 TEAC STOP 24 L
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93523

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06095

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MUELLER ASSOCIATES
BALTIMORE MD
O
21203

ROBERT B. HEEGER
A. O. SMITH CORP.
825 LEHIGH AVE. P
UNION NJ
07083

ROBERT J. HEFFERON
PA OFFICE OF COMMUNITY ENERGY
P.O. BOX 156 P
HARRISBURG PA
17120

GRAYSON HEFFNER
PRC ENERGY ANALYSIS CO.
7600 OLD SPRINGHOUSE RD P
MCLEAN VA
22102

GENE R. HEIL
AMP INC.
3711 PAXTON ST. P
HARRISBURG PA
17105

DAVID HEIM
US ASSOC INC
2944 NEBRASKA L
SANTA MONICA CA
90404

WALT HEIM
ROLLY PULASKI & ASSOC
5120 BIRCH ST L
NEWPORT BEACH CA
92660

MS JEWEL C. HEIN
DESIGNED HOME SERVICES
4717 TARRYTON CTS P
COEUNBUS OH
43228

CONRAD F HEINS
SCATTERGOOD SCHOOL
WEST BRANCH IA D
52358

PAUL HEINTZMAN
AMP INC
3711 PAXTON ST. P
HARRISBURGH PA
17105

ALAN HELENE
FLACK & KURTZ CONSULTING ENG'R
475 FIFTH AVE. P
NEW YORK NY
10017

RICHARD J. HEMBACH
CONSOLIDATED EDISON CO OF NY
4 IRVING PLACE P
NEW YORK NY
10003

RONALD L HENDERSON
US DEPT OF ENERGY ATLANTA
1466 VARNER RD NE D
MARIETTA, GA
30062

ZACH HENDERSON
AIA, INC
946 OLD CANTON ST C
ROSWELL, GA
30075

ARTHUR HENDRIKSEN
GENESEE AREA SKILL CENTER
5081 TORREY RD D
FLINT MI
48507

DANIEL E HENRY
NASA GEO C MARSHALL SPACE
FLIGHT CENTER, ATTN FA33 C
MARSHALL SPACE FLIGHT, AL
38512

ROGER HENRY
PUBLIC WORKS CANADA
SOLAR PROGRAMS OFC TUPPER BLDG
OTTAWA ONTARIO CANADA D
K1A0M2

WALTER R HENSLEY
GEORGIA POWER CO
PO BOX 4545 C
ATLANTA, GA
30302

PHILIP A HENZERLING
SALT RIVER PROJECT
PO BOX 1980 L
PHOENIX AZ
85001

KENT HERT
400 S 3RD
ELLIOTSVILLE IND

KENNETH E. HESELTON P.E.
POWER & COMBUSTION INC
7909 PHILADELPHIA ROAD P
BALTIMORE MD
21237

EARL HESS
TRACY ENGINEERS INC.
702 LISBURN RD. P
CAMP HILL PENN.
17011

RUSS HICKMAN
PORTALA VALLEY ASSOC
30 POMPONIO
PORTALA VALLEY CA
94025

HARRY HILL
AMSTAR CORP.
1251 AVE OF THE AMERICAS
NEW YORK NY
10020

THOMAS HILL
ARGONNE NATIONAL LABORATORY
400 N. CAPITAL ST NW SUITE 185
WASHINGTON DC L D O P
20001

DIANE M HILLARD
AMERICAN SUN SYSTEMS INC
8454 NW 58TH ST C
MIAMI, FL
33166

R. H. HILT
FMC CORPORATION
2000 MARKET ST. P
PHILA PA
19103

DR. RALPH E. HISE
CONSOLIDATED NATIONAL GAS SVC
11001 CEDAR AVE. P
CLEVELAND OH.
44106

BOB HITCHENS
ICI AMERICAS INC.
WILMINGTON DE P
19897

BYRON HO
BUREAU OF ARCHITECTURE
1442 W POLK ST C
CHICAGO, IL
60607

LANCE HOCH
FRANKLIN INSTITUTE SOLAR INF'N
20 PARKWAY P
PHILADELPHIA PA
19103

ROBERT M HODGES
DOW CORNING CORP
SOUTH SAGINAW RD O
MIDLAND MI
48640

JAY HOEKSTRA
SINCLAIR CO METRO PLANNING CO
511 FORT ST SUITE 400 O
PORT HURON, MI
48064

DONALD B HOFFMAN PE
ENVIRONMENTAL INTERFACES INC
2795 RANDI LANE UE L
SALEM OREGON
97303

DRAKE A. HOFFMAN
ALPHA-OMEGA SOLAR INC
P.O. BOX 5236 P
VIRGINIA BEACH VA
23455

TOBY A. HOFFMAN
PHILIP LUDEKE ASSOC.
P.O. BOX 1115 P
DOYLESTOWN PA
18901

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SOLAR WAY ENERGY STARE-A
BOX 245 ROUTE 447 P
CANADENSER PA
18325

TOM HOLLAND
MID AMERICAN SOLAR ENERGY CTR
1256 TRAPP RD D
EAGAN,MN
55121

PETER HOLLANDER
FRANKLIN RESEARCH CENTER
25 & THE PARKWAY P
PHILADELPHIA PA
19103

CRAIG S HOLOVACH
CSH DESIGN
3081 AUGUSTA ST
FLINT MI
48504

KENNETH HOLT
PENN STATE UNIV. DELAWARE CO.
25 YEARSLEY MILL RD. P
MEDIA PA
19063

WALTER E HOLTZ
CALIFORNIA POLYTECHNIC STATE U
SAN LUISOBISPO CA L
93407

BRUCE HOWIG
SUN KING
2722 W DAVIE RD O
FORT LAUDERDALE, FL
33312

JOSE P. HONRADO
LEHR ASSOCIATES
ONE PENN PLAZA P
NEW YORK NY
10001

WILLIAM L HOOVER
NASA MSFC SUPPORTING DOE
1475 JEFF RD O
HUNTSVILLE, AL
35806

JOHN S HOPKINS
3306 SPRINGHILL RD
LAFAYETTE CA L
94549

BILL HORINE
ALVIN COMMUNITY COLLEGE
ALVIN TX
77511

LAWRENCE E HORST
HORST ELECTRIC
602 S SALE ST. D
ELLETTSVILLE IN
47429

ANTHONY J HORVATH
5330 SEAMAN RD
OREGON OHIO D
43616

THOMAS HOSKENS
K K DESIGN
1429 W 36 TH ST D
MAS MN
55408

SARAH HOSPODAN
NY UNIV.
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10016

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BRIDGERS TROLLER ASSOC
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IRVINE CA
92715

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BROOKDALE CA L
95007

JOHN HOUCHIN
LEUI & CO
PO BOX 2147 1926 HAVEN DR D
EVANSVILLE IN
47714

ROBERT HOUCK
BROOKVALE CONST. CO. INC.
RD 4 BOX 846 P
EPHRATA PA
17522

PAUL A HOYING
HOYINA & HOYINA BUILDERS
13753 MC CARTYVILLE RD C
ANNA OH
45302

PATRICK C HOYLE
GM PROVING GROUND
GENERAL MOTORS PROVING GROUND
MILFORD MI D
48042

MARGO HOYT
PRC ENERGY ANALYSIS CORP
7600 OLD SPRINGHOUSE RD O
MCLEAN VA
22102

WILLIAM T HUDSON
ILI, INC
5965 PEACHTREE CORNERS E S A-4
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30011

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LEIGH L HUMMER
REYNOLDS,SMITH E HILLS
4019 BLVD CENTER DR C
JACKSONVILLE, FL
32207

EMIL K HUNSINGER
THE PHILADELPHIA CONTRIBUTIONS
212 SOUTH FOURTH ST. P
PHILADELPHIA PA
19106

BENJAMIN HUSKEY
SOLAR THERMAL SYSTEMS
200 PARK AVE. P
FLORHAM PARK NJ
07932

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NORWALK HOUSING AUTHORITY
26 MONROE ST O
SO NORWALK, CT
06854

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SOLAR SYSTEMATICS
7777 E EVELYN AVE L
SUNNYVALE CA
94086

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ARGONNE NATIONAL LABORATORY
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ARGONNE, IL
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DR. RANDAL H. IHARA
OF'E OF PLANNING & EVALUATION
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LEXINGTON KY P
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SUN KING ENTERPRISES INC.
2350 RT 10 BLDG D-10 P
MORRIS PLAINS NJ
07950

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ENERGY TECH ENGR CTR
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KAMAL S ISKANDER
LA DEPT OF WATER & POWER
111 N HOPE L
LA CA
91789

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BALTO. CHAPT. SCORE SBA
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21208

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KANSAS STATE UNIVERSITY P
MANHATTAN KS
66502

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SONOMA CO PEOPLE & ECO OPP
964 PINER RD L
SANTA ROSA CA
95407

WILLIAM L JAMES
DANIEL & ZERMACK ASSOC
2080 S STATE D
ANN ARBOR MI
48104

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46204

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CHERRY HILL NJ P
08003

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FT HUACHUCA, AZ
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BEDFORD STUYVESANT RESTORATION
1368 FULTON STREET P
BROOKLYN NY
11216

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THOMPSON PROPERTIES
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WACO TX
76701

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CSI
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LA CA
90068

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SUFFALK UNIVERSITY
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BOSTON MA
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SOLAR HEAT & COOL DEMON PROG'M
DEPT OF HUD ROOM 8158 L
WASHINGTON DC
20410

CLIFF A JONES
ST PETERSBURG ADVANCE PLANNING
205 9TH ST N C
ST PETERSBURG, FL
33731

DWIGHT JONES
HEERY & HEERY,INC
880 WEST PEACHTREE ST NW C
ATLANTA, GA
30338

RHETT JONES
REEDY CREEK UTILITIES CO.,INC.
PO BOX 40 C
LAKE BUEVA VISTA FL
32830

ROBERT E JONES
AO SMITH CORP
PO BOX 28 D
KANKAKEE IL
60901

ROBERT KC JONES JR
AMERICAN CONSUMPLEX INC
1846 DAVID WHITNEY BLDG D
DETROIT MICH
48226

GEORGE R. JORDAN
AMALGAMATED SERVICES CORP.
3466 PROGRESS DR. SUITE 204 P
CORNWELLS HEIGHTS PA
19020

KARL JOSEPHY
AVERY INTERNATIONAL
325 N ALTADENA DR L
PASADENA CA
91107

ANTHONY W. JULIANO
ALLSTATE ROOFING & SIDING CO
1522 OLD YORK RD P
ABINGTON PA
19001

DAVID P JURIST
2845 32ND STREET
SACRAMENTO CA L
95817

NORMAN JUSTUS
UNIVERSITY OF MISSOURI
SOUTHWEST CENTER RR3 C
MT VERNON MO
65712

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LLOYD LABS
BOX 338 L
TOPANGA CA
90290

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BIG APPLE SCENIC STUDIO
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WISCONSIN ELECTRIC POWER CO
231 WEST MICHIGAN ST C
MILWAWKEE WI
53201

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SOLAR THERMAL SYSTEM
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FLORHAM PARK NJ
07932

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SOL-LAR-INC
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ARNOLD MD
21012

MELVIN KANTZ
EDMUND SCIENTIFIC CO.
101 E. GLOUCESTER PIKE P
BARRINGTON NJ
08007

HARJIT KAPUR
SACRAMENTO MUNICIPAL UTILITY
P O BOX 15830 MAIL STOP 73 L
SACRAMENTO CA
95813

RUSELL KARP
71 DAVIS RD
PORT WASHINGTON NY P
11050

WAYNE KARRIS
RHEEM MFG CO
7600 S KEDZIE AVE D
CHICAGO IL
60652

ALAN D KASKE
MID-AMERICAN SOLAR ENERGY COMP
1256 TRAPP RD D
EAGAN MN
55121

FRED KATTERMAN JR
HIGH POINT ELECTRIC INC
RD4 BOX 504 P
SUSSEX NJ
07461

FRED KATTERMANN SR
HIGH POINT ELECTRIC INC.
RD4 BOX 504 P
SUSSEX NJ
07461

PAUL KATTERMANN
HIGH POINT ELECTRIC
RD4 BOX 504 P
SUSSEX NJ
07461

JODY R KATZ
JODY R KATZ C/O DISTRIBUTION
260 NEW YORK DRIVE P
FORT WASHINGTON PA
19034

MICHAEL KAYLOR
PO BOX 4052 ROUTE 4 C
FAYETTEVILLE AR
72701

TA KECK
HEAD FIRST LIGHTING
RD 9 BOX 304 P
YORK PA
17402

JAMES J KELIHER
17600 FENTON
DETROIT, MI D
48219

DOLORES KELLAM
2960 ORCHARD PLACE
ORCHARD, LAKE MI D
48033

JAMES W KELLER
US NAVEY OKC FE
OICC FE BOX 13 L
FIPO SEATTLE WA
98762

CHARLES J KELLY JR
VITRO LABORATORIES
1400 GEORGIA AVE P
SILVER SPRING MD
20910

DONALD P KELLY
NY STATE ELEC GAS
RESIONL MKT P
BINGLTANTON NY
13902

R W KELTO
TECUMSEH PRODUCTS CO
OTTAWA AND PATTERSON D
TECUMSEH, MI
49286

LEE KENNEDY
THE HEDBACK CORP
1835 NORTH NEW JERSEY ST C
INDIANAPOLIS, IN
46202

ROGER KENT
CAL STATE UNIV DOMINGUEZ HILLS
5215 S SEPULVEDA BL 14C L
CULVER CITY CA
90230

COLLEEN KETTLES
FLORIDA SOLAR ENERGY CENTER
300 SR 401 C
CAPE CANAVERAL FL
32920

THOMAS F KIBLER
INDIANAPOLIS ENERGY OFFICE
1160 CITY COUNTY BLDG
INDIANAPOLIS, IN D
46204

HILARY K KIELL
FLORIDA SOLAR ENERGY CENTER
300 STATE ROAD 401 C
CAPE CANAVERAL FLORIDA
32920

COL JOHN C KILBORN
231 WEST MULBERRY
SAN ANTONIO, TEXAS
78212

NELSON KILMEV
SUNFLOWER ENERGY WORKS
HESSTON COLLEGE C
HESSTON, KS
67062

CHARLES H KIM
AMERICANA MERCHANDISE CO
743 S SANTEG ST SUITE 300
LOS ANGELES CA
90014

KYONG ANDY KIM
LEHR ASSOCIATES
ONE PENN PLAZA P
NEW YORK NY
10001

EVERETT E KIMES
WEST BRANDYWINE TOWNSHIP
RD 1 LAFAYETTE & HIBERNIA RDS
COATESVILLE PA P
19320

EDWIN KING
ECONOMIC HOUSING & DEVEL CORP
13200 DOTY AVE SUITE 215 L
HAWTHORNE CA
90250

THOMAS A KING
MUELLER ASSOCIATES
1900 SULPHUR SPRING RD LDOP
BALTIMORE MD
21227

CHARLES KINSEY
5210 ELLIOT AVE
MINNEAPOLIS, MN C
55714

AL KIPHUT
DEPT OF ENERGY RM 11
SOLAR & INDUSTRIAL BLDG L
SALEM OR
97310

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NEW JERSEY INSTITUTE OF TECH
323 HIGH STREET P
NEWARK NJ
07102

RONALD E KIRKPATRICK
PRC ENERGY ANALYSIS CO
7600 OLD SPRINGHOUSE RD O
MC LEAN VI
22102

YUKI KISHIMOTO
POLYTECHNIC INT & STATE UNIV
COLLEGE OF ARCHITECTURE C
BLACKSBURG VA
24061

LORENZ G KISOR
SUSSMAN ASBESTOS CO
436TH 13TH D
TOLEDO, OH
43624

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COLLEGE OF ENGINEERING
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MCLEAN, VA
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426 UNITED BANK BLDG O
CHATTANOOGA TN
37401

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LEBANON CO ENERGY MNGT PROGRAM
PO BOX 899 P
LEBANON PA
17042

E FREDERICK KLEINGARTNER
CITY OF POMPANO BEACH
9351 N W 35TH MANOR C
SUNRISE, FL
33321

ROBERT KLINE
SUFFALK UNIVERSITY
41 TEMPLE P
BASTON MA
02114

WILBUR EDWARD KLINE
3492 TERRACE DRIVE
WHITEHALL PA
18052

PHILIP A KNIGHT
NORTHEAST SOLAR ENERGY CENTER
70 MEMORIAL DR P
CAMBRIDGE MA
02142

ROBERT B KOCH
RILSAN INDUSTRIAL INC
BOX 338 RD 3 P
BIRDSBORO PA
19508

SOLIS D KOPELAND
KOPELAND-SILVER INC
KOPELAND-1000 VALLEY FORGE CLE
KING OF PRUSSIA PA P
19406

M ARTHUR KOTCH AIA
ARCHITECT SUITE 413
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HOUSTON TX
77057

FRANK KREITH
SERI
1536 COLE BLVD P
GOLDEN CO
80401

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WASHOE COUNTY PUBLIC WORKS
1205 MILL STREET PO BOX 11130
RENO NV L
89520

THOMAS R KULP
HELIOTHERM INC
BOX 115 P
N WALES PA
19454

ALBERT KURTZON
WINDOWS & LIGHTING SYSTEMS INC
734 N PASTORIA AVE L
SUNNYVALE CA
94086

CERNYW K KLINE
LANSING COMMUNITY COLLEGE
419 N CAPITAL AVE D
LANSING, MI
48901

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BIG APPLE SCENIC STUDIO LTD
PO BOX 767 150 W 46 STREET P
NEW YORK NY
10036

STANLEY KON
DEH ENGRG SUCS US ARMY
SETTFIELD BLDG 300 L
WHEELER AFB HI
96857

WIC KORMEIER
INTERTHERUN INC
3800 PARK AVE D
ST LOUIS, MO
63110

C THOMAS KRECK
7 E WOOD STS
VINELAND NJ P
08360

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ST JOSEPH COLLEGE
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WEST HARTFORD CT
06117

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US DEPT HUD
26 FEDERAL PLAZA P
NEW YORK NY
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ROLLIN R LA FRANCE
MITCHELL GIURGELA ARCHITECTS
12 SOUTH 12 STREET P
PHILADELPHIA PA
19107

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LACILLADE LUMBER CO
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WILLIAMSTOWN UT
05679

DAVE LACKSTROM
SJC CORP
206 WOODFORD AVE D
ELYRIA, OH
44036

B L LAFOON
REYNOLDS METALS CO
6601 W BROAD ST P
RICHMOND VA
23261

ALVIN LAI
ANSI
1430 BROADWAY C
NEW YORK NY
10018

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STATE OF CALIF
DEPT OF WATER
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PORTLAND AREA INDIAN HEALTH SE
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PORTLAND OR
97204

DONALD LANDSMAN
INTERNAL REVENUE SERVICE
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WASHINGTON DC
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FLAGALA CORP
212 1/2 WILSON AVE C
PANAMA CITY FL
32401

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FALLSTON GENERAL HOSPITAL
220 MELTON AVE P
FALLSTON MD
21047

MAURICE LANGSEV
3045 ALANAPUAA 313
HONOLULU HI L
96818

GREGORY M LANGSTON
LANGSTON REFRIGERATION SERVICE
208 WELLINGTON DRIVE
WARMINSTER PA
18974

DAVID LANTRIP PE
WHOLE EARTH ENGR
4920 OCEAN AIRE STR L
OXNARD CA
93030

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R W LANZ & ASSOC
4517 NEW FRANKEN ROAD P
NEW FRANKEN WI
54229

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LARKIN & CYWINSKI
225 SOUTH 15 STREET P
PHILADELPHIA PA
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GRAND RAPIDS, MI
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NO HOLLYWOOD CA
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LADD WILLIAMS REALTOR
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1513 S 6TH ST D
ELKHART, IN
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EDMOND A LEBLANC
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FRANK LEBMAN
EWING C RIZZIO CHERRY PARKSKY
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19106

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STATE OF CALIFORNIA
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95814

MARLOW LEE
H & H TUBE & MFTR
263 FORMAN AVE P
DETROIT MI
48209

DONALD E LEE
TOBLINSON,NARBURN,YURK,ASSOC.
705 KELSO D
FLINT, MI
48506

KENNETH S LEE
OHIO STATE UNIVERSITY
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48103

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MACOMB COUNTY COMMUNITY COL
14500 E TWELVE MILE D
WARREN, MI
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2301 MARKET ST 518-1 P
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GIFFELS ASSOC
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REXDALE ONTARIO, CANADA
M9U5P3

VERNE LEHMBERG
LEE COLLEGE
LEE DRIVE D
BAYTOWN, TX
77520

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CHALMETTE LA O
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CORNING GLASS WORKS
HOUGHTON PARK C-7 P
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91604

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REINHARD LESSER & ASSOC
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LEE MAYER & COMPANY
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LAKE FOREST, IL
60045

MARSHALL LEVINE
INSTITUTE FOR HUMAN DEVELOPMEN
538 OLD EAGLE SCHOOL RD P
WAYNE PA
19087

LAWRENCE LEVY
NORTHEAST SOLAR ENERGY CENTER
70 MEMORIAL DR P
CAMBRIDGE MA
02142

DAVE LEWIS
LENNOX IND
1400 MANHATTAN AVE L
FULLERTON CA
92631

JOE LEWIS
CITY OF TEXARKANA AR
PO BOX 2711 L
TEXARKANA AR
75501

MALCOLM LEWIS
220 PARK AVE
LAGUNA BEACH CA L
92651

TH LEWIS
ELLIOT-LEWIS CORPORATION
2701 GRANT AVE P
PHILADELPHIA PA
19114

VIRGINIA LEWIS
MALCOLM LEWIS ASSOC
220 PARK AVE L
LAGUNA BEACH CA
92651

MARY LEYDEN
CITY OF MENLO PARK
CIVIC CENTER L
MENLO PARK CA
94025

RAFAEL V LICEA
CITY OF MIAMI BLDG DEPT
3319 PAN AMERICAN DR D
MIAMI FL
33131

SUI LIN
CONCORDIA UNIVERSITY
1455 DE MAISONNEUVE BLVD WEST
MONTREAL CANADA P
H3G1M8

EUGENE H LINBERG
US DEPT OF HOUSING & URBAN DEV
2500 WILSHIRE BLVD ROOM 410 L
LOS ANGELES CA
90057

PETER LINDABURY
ENERGY CENTER SYRACUSE UNIVERS
324 OSTROM AVE P
SYRACUSE NY
13210

VICTOR L LINDBERG
FORD MOTOR CO
GTC 25500 W OUTER DR D
LINCOLN PARK, MI
48146

ARTHUR H LITKA
FLA SOLAR ENERGY CENTER
300 ST RD 401 D
CAPE CANAVERAL FLA
32920

ROBERT K LITTLE
RKL CONTROLS INC
ARK RD P
LUMBERTON NJ
08048

GERALD LIVERETTE
N E FLORIDA SOLAR ENERGY ASSOC
2373 FERNVIEW DR C
ORANGE PARK FL
32073

MRS GERALD LIVERETTE
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2373 FERNVIEW DR D
ORANGE PARK FL
32073

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94086

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203 GENESEE P
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13021

ALAN LONG
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56 QUEEN ELIZABETH BLVD D
TORONTO ONTARIO, CANADA
M8Z1M1

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WESTLAKE CA
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36604

ROBERT E LOSEY
WYLE LABORATORIES
7800 GOVERNORS DR P
HUNTSVILLE AI
35807

STERNS B LOTT
UNITED STATES POSTAL SERVICE
RM 8912 USPS HEADQUARTERS O
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20260

HERMAN W LUBELL PE
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LONGBOAT KEY FL O
33548

RICHARD LUCAS
INYO COUNTY
207 W SOUTH ST L
BISHOP CA
93514

R B LUCKENBACH
CREEK RD & GRIST MILL ROAD
GLEN MILLS PA P
19342

WILLIAM P LULL
JAMES ASSOC ARCH/ENG INC
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INDIANAPOLIS, IN
46205

MR GREGORY LUNA
210 STARDUST
SAN ANTONIO, TEXAS
78228

ALEXANDER LURKIS
199 JERICHO TURN PIKE
FLORAL PK NY P
11001

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CUSTOM CARPENTRY
9150 DOTY RD D
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06443

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46204

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SAN BERNARDINO CA
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DAVID MAGHEN
STORMS & LOWE
606 WILSHIRE BLVD 204 L
SANTA MONICA CA
90401

JEROME MAIMAN
EB OREILLY & ASSOC INC
541 MAISON PLACE P
BRYN MAWR PA
19010

S S MALHOTRA
SCIENCE APPLICATIONS INC
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60521

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95695

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COPEMISH, MI D
49625

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90601

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08540

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PROTEUS INC
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VISALIA CA
93277

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TRINITY UNIV
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SAN ANTONIO TX
78284

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SUNTEK RESEARCH ASSOC
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CORTE MADERA CA
94925

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MCDONALD & MCDONALD
66 N MONTEREY P
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36604

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RSMCA
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RICHBORO PA
18954

CECIL W MESSER
NASA-MARSHALL SPACE FLIGHT CTR
FA32
HUNTSVILLE AL
35812

MICHAEL MESSINA
658 W ROLLING RD P
SPRINGFIELD PA
19064

METZ DICK
AMERICAN MOTOR INN'S
1917 FRANKLIN RD C
ROANOKE VA
24014

C VIRGIL METZLER
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6901 BIRCHTEN AVE L
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FLORHAM PARK NJ
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ROME NY
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GEORGE MICHEL
TOWN OF WOODBRIDGE
1047 RACE BROWN RD P
WOODBRIDGE CT
06525

MARGARET MILES
SUFFOLK COUNTY
OFC OF COUNTY EXECUTIVE BLDG P
HAUPPZUGE NY
11787

ROBERT L MILLANESE
PEPSI-COLA
ANDERSON HILL RD P
PURCHASE NY
10577

DONALD L MILLER
PENN STATE UNIVERSITY
CAPITOL CAMPUS P
MIDDLETOWN PA
17057

PAUL MILLER ENVIRONMENTAL ENERGIES MRKTG PO BOX 155 P DANVILLE VT 65828	RIVANNA MILLER 247 S FARRAGUT ST P PHILADELPHIA PA 19139
ROBERT N MILLER SOUTHERN NE TELEPHONE COMPANY 195 CHURCH STREET 6TH FLOOR P NEW HAVEN CT 06500	STEVEN MILLER 2477 VALLEY RD P E PETERSBURG PA 17520
GARY A MILLHOLLEN SUN ENERGY BUILDERS 5838 ROBERTSON L CARMICHAEL CA 95608	ANTONIO MINARDI UNIVERSITY OF CENTRAL FLORIDA PO BOX 25000 O ORLANDO FL 32816
DANIEL MIRCHEFF 2947 BRIARWOOD DR TORRANCE CA L 90505	JAMES MITCHELL 2044 LOCUST ST P PHILADELPHIA PA 19103
DAVID I MITCHELL SOL-CON 30600 SPRINGLAND O FARMINGTON HILLS, MI 48018	STEVEN C MITCHELL SOL-CON 30600 SPRINGLAND O FARMINGTON HILLS, MI 48018
JIM MIYAO PAYNE AIR CONDITIONING CO 16950 EAST CHESTNUT ST L CITY OF INDUSTRY CA 91749	JOHN V MIZZI PO BOX 455 P GOLDEN BRIDGE NY 10526
YVONNE MOFFAT FLORIDA SOLAR ENERGY PRODUCTS 2244 S MONROE ST O TALLAHASSEE FL 32304	ANIKO MOLNAR BECHTEL CORP PO BOX 3965 L SAN FRANCISCO CA 94119
PAUL F MONAGHAN 521 COLBORNE ST PO BOX 428 O LONDON ONTARIO, CANADA N6B2T6	WALTER M MONKIEWILZ JR EXXON ENTERPRISES PO BOX 592 O FLORHAM PARK NJ 07932
JAMES MONROE 23 FAIRLANE DR P CANTON NY 13617	RICHARD MONTGOMERY DOW CORNING CORPORATION 521 COLBORNE ST MIDLAND, MI N6B2T6

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BARTOW,FL
33830

CAREY C MORGAN
121 C PLANTATION COURT EAST
TEMPLE TERRACE FL O
33617

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8301 GREENSBORO DR P
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22102

CLIFFORD E MORN
507 CASS ST
MONROE, MI D
48161

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POCONO MOUTAIN HIGH SCHOOL P
SWIFTWATER PA
18370

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AIA RESEARCH CORP
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20006

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MAINLINE BLDG & DEVELOPEMENT
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HAVERTOWN PA
19083

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SOLARIES INC
6600 US 301 N AIRPORT MALL O
SARASOTA FL
33580

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MASEC
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EAGAN, MN
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ENERGY & MINERAL DEPT 113
STATE OF NEW MEXICO
WASHINGTON AVE
SANTA FE NM

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INVESTMENT CONCERN
3219 BELLE CT
ROYAL OAK,MI
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KORBULY-GRAF INC ARCHITECTS
2513 LINCOLNWAY
SOUTH BEND, IN
46628

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DETROIT, MI
48226

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BIRMINGHAM AL
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ADVANCED ENERGY SYSTEMS
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TABB VA
23602

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MOWERY CONSTRUCTION
100 BETTY LN D
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02199

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215 W WRIGHTWOOD AVE O
ELMHURST IL
60126

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23261

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19105 ANNAROUS WAY O
C BURG MD
20760

ROBERT E MURPHY
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200 PLANT AVE P
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19087

STEPHEN R MURPHY
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3091 MAYFIELD ROAD ROOM 217 O
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44118

LARRY MURPHY
IBM CORP
150 SPARKMAN DOPL
HUNTSVILLE, AL
35805

LAWRENCE M MURPHY
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1536 COLE BLVD D
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HALSTEAD INDUSTRIAL PRODUCTS
NORTH FALLS BLVD O
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MYRON L MYERS
NASA/GCMSFC
GEO C MARSHALL SPACE FLIGHT CT
MSFC AL O
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NORTHERN DIVISION
NAVAL AIR DEVELOPMENT CENTER P
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75 SPRING ST RM 702 C
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ROOFING & SHEET METAL CONTRS
4333 RIVER DR P
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JOHN O'HARE
CLARK EQUIPMENT CO
CIRCLE DR D
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REO ENGINEERING
327TH & OAK GROVE RD RR2 O
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DEATSVILLE AL
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N B OSTRYE
GENERAL DEVELOPMENT & SUPPLY
RT 1 BOX 342 O
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150 BROADHOLLOW RD P
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1527 C ROAD O
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33470

KAREN OUZTS
SMALL HOMES COUNCIL/UN OF IL
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UNIVERSITY OF FLORIDA
138 NO 13TH PL O
LANTANA FL
33462

ALFRED PANEPINTO
MONTEBELLO
SPRING MT,PA P
19478

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NORTHEAST SOLAR ENERGY CENTER
70 MEMORIAL DR P
CAMBRIDGE,MA
02142

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400 CARTLAND AVE O
WINTER PARK FL
32789

JOHN PATTEN
HOYEM & BUSSO ASSOC
974 HIGHLANDER O
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ARGONNE NATIONAL LAB
BLDG 362 L
ARGONNE IL
60439

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2429 SEMINOLE ST O
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CHEVRON OIL FIELD RESEARCH CO
PO BOX 446 L
LA HABRA CA
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190 TRUMBULL ST P
HARTFORD,CT
06103

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ARGONNE IL
60439

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KINGSLAND ST BLDG 105 P
NUTLY,NJ
07110

JOHN M PEEPLES
CALIF PUB UTIL COMM
STATE BLDG CIVIC CENT RM 5178
SAN FRANCISCO CA L
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SANTA CLARA CA
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20545

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POMPTON PLAINS,NJ
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32604

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9770 CULVER BLVD L
CULVER CA
90230

PERCIVAL E PEREIRA
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PRINCETON,NJ
08540

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100 WILSHIRE BLVD L
SANTA MONICA CA
90401

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NATL SOLAR INFO CENTER
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CROYDON,PA
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LAWRENCE BERKELEY LABORATORY
1 CYCLOTRON ROAD L
BERKELEY CA
94709

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PHOENIX SOLAR CENTER
2925 N 24 ST L
PHOENIX AR
85016

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JP INDUSTRIES
103 LAKE SEARS DRIVE D
WINTER HAVEN
33880

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BIG CITY AIR CONDITIONING INC
12117 PRAIRIE AVE L
HAWTHORNE CA
90250

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ELLICOTT CITY,MD
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28144

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SOUTHPORT CT P
06490

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RT 1 PO BOX 170 L
WINTERS CA
95654

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POLK CONSTRUCTION CO
224 MYRTLE ST L
HALF MOON BAY CA
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19139

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85020

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1740 MAPLE ST
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60559

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CITY OF EAST LANSING
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COLLEGE OF THE VIRGINIA ISLAND
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TATAR ROSENTHAL INC
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BEL AIR,MD
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SOLARGY INC
22028 VENTURA BLVD SUITE 205 L
WOODLAND HILLS CA
91364

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CLAYTCN MO
63105

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92131

JIM ROTHMAN
MASEC
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NICK SALAMONE
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PLAYA DEL REY CA
90291

NURY SALAMONE
MARINA SOLAR
405 CULVER BLVD SUITE 6 L
PLAYA DEL REY CA
90291

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4 FAIRLAWN P
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LAWRENCE BERKELEY LABORATORY
1 CYCLOTRON ROAD L
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94709

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CITY OF BAYONNE
630 AVENUE C P
BAYONNE NJ
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SANDS & SPERLING ARCHITECTS
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LEROY A SAYRE
INTERNAT'L CONFERENCE OF BUILD
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WHITTIER CA
90601

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LUCAS LAND CO.
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RANCHO CUCAMONGA CA
91730

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ROOM 849-73 TREMONT ST P
BOSTON MA
02178

CHARLES G SCHIFF
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SPRINGFIELD MA
01109

LAURENCE SCHMEIDLER
70 MEMORIAL
CAMBRIDGE MA P
02142

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325 CRAWFORD ST D
TERRE HAUTE, IN
47807

DALE SARTOR
INTERACTIVE RESOURCES INC.
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RICHMOND CA
94801

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NEW ORLEANS LA
70119

GERARD SCHOEN
SOLAR POWER CORPORATION
4124 TOULOUSE STREET C
NEW ORLEANS LA
70119

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NAVAL NUCLEAR POWER UNIT
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AQUAPPLIANCES INC
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CALIF PUBLIC UTILITIES COMMI'N
455 GOLDEN GATE AVE ROOM 2011
SAN FRANCISCO CA L
94102

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CONSTRUCTION MGMT ASSOC INC
81 PARK TERR P
W ORANGE NJ
07052

HENRY SCHWAB,JR
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HAVERTOWN PA P
19083

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OPPORTUNITY BOARD MONT CO
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LAUREL MD P
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TOWNSHIP OF MARPLE
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19008

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DON B SEMEYN
DOW CHEMICAL CC
4603 ROANOKE CT D
MIDLAND, MI
48640

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SENTE HANDRATH & RUBEL
1955 RAYMOND DR G
NORTHBROOK IL
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SOLAR DESIGN ASSOCIATES
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CANTON MA
02021

NORMAN R SERIGSTAD
H.U.C.
17712 VILLAMOURA DR L
POWAY CA
92064

RALPH SESULVEDA
SONOMA CO PEOPLES FOR ECON OPP
964 PINER ROAD L
SANTA ROSA CA
95401

MQ SHAIKH
ROSE HALL, ROOM 305 O
AUBURN UNIVERSITY
AUBURN AL
36830

JEROME A SHAMROCK
JEROME A SHAMROCK & ASSOC.
3002 MIDVALE AVE L
LOS ANGELES CA
90034

WAYNE E SHANNON
LOCKHEED PALO ALTO RES. LAB
3251 HANOVER STREET L
PALO-ALTO CA
94304

B I SHARMA
OWENS-CORNING FIBERGLAS
TECHNICAL CENTER C
GRANVILL, OH
43023

GEORGE C. SHAW
EDWARD CARSON BEALL & ASS
23727 HAWTHORNE BLVD L
TORRANCE CA
90505

SCOTT L SHAW
SWAIN DEVELOPMENT INC
3001 EL GRECO CT C
BRANDON FL
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TRACY ENGINEERS INC
BOX 702 LISBURN RD P
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DAVE SHELTON
SHELTON & ASSOCIATES
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SHEPHERD ENGINEERING ASSOC
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TOMS RIVER NJ
08753

MICHAEL SHEPPARD
COONEY ENGR CO
2349 SIX MILE RD D
SOUTH LYON, MI
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WM C SHERBIN
WESTINGHOUSE SOLAR H & C
5205 LEESBURG PIKE SUITE 201
FALLS,CHURCH,VA
22041

KEN SHIFRIN
239 SCHENCK AVE
GREAT NECK NY P
11021

JEFFERSON SHINGLETON PE
MUELLER ASSOCIATES INC
1900 SULPHUR SPRING RD P
BALTIMORE MD
21227

ROY SHIVE
GOV OFC SC DIV OF ENERGY
RESOURCES,EDGAR BROWN BLDG
1205 PENDLETON ST C
COLUMBIA SC 29201

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THERMAL TECHNOLOGY CORP.
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SNOWMASS CO
81654

DR SIDNEY SHORE
TOWNE BLDG/D3
DEPT. OF CIVIL & URBAN ENG'S
PHILADELPHIA PA P
19104

DAVID SHREVE
GERRY SHREVE,ASSOC,INC
3000 TOWN CENTER SUITE 410 D
SOUTHFIELD, MI
48075

GERRY SCHREVE
GERRY SCHREVE ASSOC INC
3000 TOWN CENTER SUITE 410 D
SOUTHFIELD, MI
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36 STREET AT SPRUCE P
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2126 EDGEWOOD DR C
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20 WARREN ST P
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RUDOLPH,SIDES
901 LAWNDALE
ROYAL OAK D
ROYAL OAK, MI
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AMES LABORATORY-DOE
1506 WILSON AVE D
AMES, IA
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PENN STATE UNIV DELAWARE CO
25 YEARSLEY MILL RD P
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996 MACKINAW HWY D
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LEONARD SIERADSKI
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PETOSKEY, MI C
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1557 DOLORES STREET
SAN FRANCISCO CA
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STEPHEN SILVERSTEIN
1557 DOLORES ST
SAN FRANCISCO CA
94110

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1320 S DIXIE HIGHWAY C
CORAL GABLES FL
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2 WATERVIEW RD APT E-6 P
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SANTA MONICA CA
90401

ANDREW SIMPSON
WAMY COMMUNITY ACTION INC
PO BOX 552 C
BOONE NC
28607

H SINGH
ARGONNE NAT'L LAB
9700 S CASS AVE P
ARGONNE IL
60439

ISHWAR,SINGH
DEPT OF CHEMISTRY
MOHAWK COLLEGE C
HAMILTON ONT, CANADA
L9G1E6

WILLIAM A. SINGLETON
BURNS & MC DONELL ENGR CO
PO BOX 173
KANSAS MO
64141

MICHAEL SIZEMORE
SIZEMORE/CRS
1900 EMERY ST., NW,STE 210 C
ATLANTA GA
30318

ROGER SKELTON
HORIZON ENTERPRISES,INC
1011 NW 6 ST O
HOMESTEAD FL
33030

EDWARD PAUL SKIBITZKE
AIA ARCHITECT
700 ALMA REAL DR
PACIFIC PALISADES CALIF.
90272

WALTER SKOGLUND
CITY OF OTSEGO
117 E ORLEANS D
OTSEGO, MI
47078

ROGER SLOAN
MISSION VIEJO A/C & HEATING
21947 YELLOWSTONE LANE L
EL TORO CA
92630

JOSEPH C SLOANE
SLOANE PLG HTG & COOLING CO
1117 MAY ST D
LANSING, MI
48906

GREG SMITH
GREGG-GANGI DEVELOPMENT
130 SO JACKSON ST L
GLENDALE CA
91205

HAROLD SMITH
DEPT OF GENERAL SERVICES MD
301 W PRESTON ST ROOM 1405 P
BALTIMORE MD
21201

JEFFREY M SMITH
OPM-ENERGY DIVISION
80 WASHINGTON ST P
HARTFORD CT
06115

LINDA J SMITH
PRC/ENERGY ANALYSIS CO
7600 OLD SPRINGHOUSE RD PIKE O
MCLEAN VA
22102

MR MACLYN L SMITH
LEIGH WAYNE LTD
P.O. BOX 361 L
VERDUGO CITY CA
91046

SUSAN L SMITH
SULLIVAN COUNTY CO'E EXTENSION
59 N MAIN ST 3 FLOOR P
LIBERTY NY
12754

JAY W SMITH
ADM BLDG COUNCIL OF INDIANA
215 N SENATE AVE D
INDIANAPOLIS, IN
46204

NANCY SMOW
S.C. P.E.O.
964 PINER RD L
SANTA ROSA CA
95401

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PORTLAND AREA INDIAN HEALTH
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97204

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TERRI L SNYDERMAN
INST'E OF ENERGY CONVERSION
U OF DE ONE PIKE CREEK CENTER
WILMINGTON DEL P
19808

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DOW CORNING CORP
3901 S SAGINAW RD PO BOX 15920
MIDLAND, MI
48640

LORNN SODERSTRONN
CARTER HAWLEY HALE STORES INC.
550 S. FLOWER ST. L
LA CA
90071

FRANSIS SONICO JR
EDUCTRONICS
1228 WEST M ST L
WILMINGTON CAL
90744

THOMAS J SOTOLONGO
AMP INC
855 SO BAYWAY BLVD #C-806 O
CLEARWATER BEACH FL
33515

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DOE
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91304

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FORD MOTOR CO
GLASS TECH CTR 25500 W OUTER D
LINCOLN PARK, MI
48146

RALPH W SPARGO
AROSA-DEVELOPMENT & MANAGEMENT
2915-C RED HILL AVE SUITE 106
COSTA MESA CA L
92627

HARRY M SPARKS JR AIA
ARCHITECT LANDSCAPE & PLANNER
P.O BOX 175 SUITE 305 L
FRANKFORT KY
40602

PHYLLIS SPERLING
SANDS & SPERLING ARCHITECTS
610 WEST END AVENUE P
NEW YORK NY
10024

ROLAND SPRESSART
DIV OF BLDG & CONSTRUCTION
STATE OF NJ PO BOX 1243 P
TRENTON NJ
08625

CRAIG ST CYR
ST CYR PLUMBING & HEATING
PO BOX 742 D
BENNINGTON, VT
05201

JOSEPH ST CYR AIA
SOLAR WIND ENERGY SYSTEMS INC
10833 FARMINGTON RD D
LWNOIA, MI
48150

GILBERT H STACY
DEERFIELD ACADEMY
ALBANY ROAD P
DEERFIELD MA
01342

ARTHUR J STAINNER
CMI SYSTEMS COOL-C-MATIC
38 SOUTH STREET P
MANVILLE NJ
08835

LARRY STAINS
RODALE PRESS INC NEW SHELTER M
33 E MINOR ST P
EMMAUS PA
18049

E L STANLEY
ALTERNATE ENERGY SYSTEMS
BOX 36 P
GWYNEDD VALLEY PA
19437

JEREMY STARCBIN
TOTAL SOLAR INC
615 ASHBOURNE RD P
ELKINS PARK PA
19117

STANLEY O STARR
FLORIDA SOLAR ENERGY CENTER
300 STATE ROAD #401 C
CAPE CANAVERAL FL
32922

BERNICE T STEADMAN
CRESTHAVEN CORP
1172 KNOLLCREST CT D
TRAVERSE CITY, MI
49684

ELLIS J STEARNS
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COCOA BEACH FL
32931

ARTHUR STEIKER
MATHTECH INC
10 FRANKLIN CORNER RD P
LAWRENCEVILLE NJ
08648

MARILYN STEIN
HUDSON PUBLISHING CO
289 S. SAN ANTONIO RD L
LOS ALTOS CA
94022

MORRIS H STEIN
STEIN, HINKLE,DAWE & ASSOC.ARC
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48910

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1015 E WASHINGTON AVE D
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53701

MITCH STEINMAN
SANDERS & THOMAS
VALLEY VIEW APT YORKTOWN 9 P
POTTSTOWN PA
19464

RAYMOND STERLING
UNDERGROUND SPACE CTR UNIV OF
MN II MIN MET BLDG 221 CHURCHC
MINNEAPOLIS, MN
55455

REBECCA STEWART
CITY OF ST PETERSBURG PLANNING
205 9TH ST NORTH ROOM 202 C
ST PETERSBURG FL
33701

HERMAN STIGLMEIER
RT 1 BOX 5175 KOLOA
KAVAL HI L
96756

DAVID HK STILES
CERTIFIED SOLAR SYSTEMS INC
1500 W CHURCH ST C
ORLANDO FL
32805

HAROLD STOKES
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DEARBORN HEIGHTS, MI D
48127

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EI-63 RM 4530 P
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20461

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SBEC C
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30338

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5885 HAVEN AV. L
ALTA LOMA CA
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PHILA PA
19103

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200 N. MAIN ST ROOM 890 L
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90012

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CANTON MA
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SPRINGFIELD IL P
62702

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ALBUQUERQUE NM
87103

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STAR SYSTEMS SOLAR H/C
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ASHTABULA, OH
44004

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SUN DESIGN
ST GERMAIN, WI C
54558

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19013

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CITY OF GARDENA
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GARDENA CA
90247

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NEVADA POWER CO.
CTSD L
LAS VEGAS NV

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U.S. ASSOC. INC
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SANTA MONICA CA
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ENERGY PERSPECTIVE
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SAN DIEGO GAS & ELECTRIC
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SAN DIEGO CA
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AIRCRAFTMAN
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GRAND ISLAND, NY
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DENVILLE NJ P
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ROLLINS COLLEGE
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LONGWOOD FL
32750

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147 S LOS RABLES AVE E
PASADENA CA L
91101

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SA BRUNO CA
94099

NORMAN TEPLEY
DEPT OF PHYSICS
OAKLAND UNIVERSITY O
ROCHESTER, MI
48063

RICHARD T TERRY
RT ENTERPRISES
3 BARRACUDA LANE OCEAN REEF C
KEY LARGO O
33037

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54913

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FAIRFAX VA P
22032

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VA POLY INST & STATE UNIV
MECHANICAL ENGINEERING C
BLACKSBURG VA
24061

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605 CANTERBURY HILL
SAN ANTONIO, TEXAS
78209

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AUTOMATION INC INC
VITRO SER'S DIV IND PARK C
FORT WALTON BEACH
32548

RON S THOMPSON
GR THOMPSON
801 FRANKLIN ST 605 L
OAKLAND CA
94607

MARY THROCKMORTON
57 PARK STREET
BORDENTOWN NJ P
08505

MRS WILLIAM THURE
4365 OCEANVIEW AVE
MALIBU CA L
90265

WILLIAM THURE
4365 OCEANVIEW AVE
MALIBU CA L
90265

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ENVIRONMENTAL INTERFACES INC
2795 RANDI LANE NE L
SALEM OR
97303

JOHN TILLER DIRECTOR
COUNTY OF DELAWARE
COURT HOUSE P
MEDIA PA
19063

SAMUEL E TILLIS
SALEM COMMUNITY COLLEGE
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TENNS GROVE NJ
08069

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NAVAL POSTGRADUATE SCHOOL
CODE 62 TS L
MONTEREY CA
93940

BADAWI TLEIMAT
UNIV. OF CALIF.
47TH E HOFFMAN BLVD L
RICHMOND CA
94804

NICHOLS TODARO
PRATT CENTER
275 WASHINGTON AVE P
BROOKLYN NY
11205

MIKE A TODOSCIVK
GENERAL MOTOR'S PROVING GROUND
GENERAL MOTORS RD D
MILFORD, MI
48042

JOSEPH TOMLINSON
SUNRISE SOLAR SYSTEMS
268 ROCK AVE P
NORTH PLAINFIELD NJ
07063

JOHN H TONER III
17634 FENTON
DETROIT, MI
48219

GARREN E. TOOKER
H.K FERGUSON CO.
44 MONTGOMERY ST L
SAN FRANCISCO CA
94104

MICHAEL TRACEY
SEA ISLE CITY
PO BOX 125 P
SEA ISLE CITY NJ
08243

KATHY TREMBLAY
233 WYAWDOTTE ST E
SUNRAY SOLAR SYSTEMS LTD D
WINDSOR ONT, CANADA
N9A3H

JERRY TROOPER
COMET BUILDERS INC
12364 WILSHIRE BLVD SUITE 1 L
LOS ANGELES CA
90025

NATHAN TROOPER
COMET BUILDERS INC
12364 WILSHIRE BLVD SUITE 1 L
LOS ANGELES CA
90025

JAMES MICHAEL TUFFO
CAMBRIDGE LEE INDUSTRIES
500 LINCOLN STREET P
BOSTON MA
02134

DAVID TUK
USC
3119 EL CCMINITO L
LA CRESCENTA CA
91214

KAL TURKIA
SOUTHERN SOLAR ENERGY CENTER
2300 PEACHFORD RD SUITE 1250 D
ATLANTA GA
30338

CHARLES G TURLEY
MARRIOTT CORP
MARRIOTT DRIVE P
WASHINGTON DC
20058

JOHN A. TURNQUIST
AIRESEARCH MANUFACTURING CO
2525 W. 190TH. ST L
TORRANCE CA
90509

KEITH UNFRIED
IVY TECH COLLEGE
541 STANLEY AVE D
EVANSVILLE, IN
47711

STEVE URAINE
ENVIRONMENTAL DESIGNS
200 PIER AVE 9 L
HERMOSA BEACH CA
90254

STANLEY J VACHTA
ARGONNE NAT'L LABORATORY
9700 S CASS AVE D
ARGONNE, IL
60439

ROBERT E VAN BUSKIRK
MASTER BUILDERS
158 W HIGHLAND AVE L
SIERRA MADRE CA
91024

SIM VAN DER RYN
VAN DER RYN,CALTHCRP & PARTNER
PO DRAWER F L
INVERNESS, CA
94937

WARREN VANDENHOFF
APPLIED TECHNOLOGY
1637 PONTIUS AVE L
LOS ANGELES CA
90025

GARY P VANDERBILT
NJ DEPT OF HEALTH
216 W PARK AVE P
TRENTON NJ
08610

RICHARD E VASSEY
VASSEY & CO INC
115 BLACK HORSE PIKE P
HADDON HEIGHTS NJ
08085

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BOX 79 715 STADIUM DR O P
SAN ANTONIO
78284

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DIST HGTS MD
20028

HARVEY VERNIER
AIA ARCHITECTS
114 W 4TH AVE L
MOSES LAKE WA
98837

WILLIAM L VIAR PE
WATERLAND VIAR & ASSOCIATES
ONE PIKE CREEK CENTER SUIT 204
WILMINGTON DE P
19808

EDWARD T VILAS
VITRO LABORATORIES
14000 GEORGIA AVE P
SILVER SPRING MD
20910

JOHN A VINCENT
FLUOR CORP.
8603 WOODPECKER AVE L
FOUNTAIN VALLEY CA
92708

THOMAS E VITALE
CITY OF PHILA
RISING SUN & BENNON P
PHILADELPHIA PA
19111

GARY C VLIET
DEPT OF MECH ENG UNIV OF TX
TAYLOR HALL 173 UT O
AUSTIN TX
78712

BARRY VON-TOBEL
VON-TOBEL OF WINAMAC INC
115 W PEARL ST D
WINAMAC, IN
46996

JOSIP VRESK
ARGONNE NAT'L LABORATORY
9700 S. CASS AVE D
ARGONNE, IL
60439

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AGWAY PETROLEUM
PO BOX 365 P
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18946

GEORGE L WAGENSFILLIER
33 IAWOOD RD
LEVITTOWN PA P
19057

CHARLES J WAGNER JR
CITENS & SUBTROPICAL PRODUCTS
600 AVE S NW PO BOX 1909 O
WINTER HAVEN FL
33880

CHARLES M WAGNER N22
EG & G INC
P.O BOX 1912 L
LAS VEGAS NV
89101

GERALDINE R WAGNER
1321 MALLARK ST
LAS VEGAS NEV L
89128

W D WAGONER
UNIV OF NEW ORLEANS
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70122

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ED WAITE
ARGONNE
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IDAHO FALLS ID
83401

OMI G WALDEN
DEPT OF ENERGY
20 MASSACHUSETTS AVE L
WASHINGTON DC
20545

EARL W WALKER JR
HAMPTON ROADS OIL CO
2522 FLORIDA AVE C
NORFOLK VA
23513

RAY WALKER
SOUTHERN CALIFORNIA EDISON CO
P.O BOX 800 L
ROSEMEAD CA
91770

J ROBERT WALKER
LEHIGH COUNTY COMM COLLEGE
2104 HIGHLAND P
ALLENTOWN PA
18104

JEROME WALKOWSKI
WISCONSIN HOUSING FINANCE AUTH
131 WEST WILSON D
MADISON, WI
53702

ROBERT H WALLACE
JARRELL HAY WALLACE & CHAPMAN
ONE WEST SECOND STREET P
MEDIA PA
19063

RONALD G WALLACE
AMERICAN SOLAR RESOURCES LTD
29 CLOVER DRIVE P
SMITHTOWN NY
11782

STEPHEN WALLACE
NORTHEAST SOLAR ENERGY CENTER
70 MEMORIAL DRIVE P
CAMBRIDGE MA
02142

BEN WALLACE
ENERGY EDUCATION OFFICE
86 PARKHURST D
PONTIAC, MI
48058

DR MARK WALLIN
KLING-LINDQUIST INC
1401 AERA ST P
PHILADELPHIA PA
19102

LARRY WALSH
BALTIMORE COUNTY MARYLAND
COURTHOUSE ROOM M03 400 WASH A
TOWSON MD P
21204

TOM WALTER
CONFINEMENT LIVESTOCK SYSTEMS
PO BOX 497,1707 21ST ST D
ELDORA, IA
50627

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CUNNINGHAM ENGR,INC
4891 QUARTON RD D
BIRMINGHAM, MI
48010

MARK WARCHOL
VACUMET FINISHING,INC
4662 PUTTYGUT RD D
ST CLAIR, MI
48079

ROBERTSON WARD
ROBERTSON WARD ARCH
21 W ELM ST P
CHICAGO IL
60610

JAMES F. WARNOCK
WESTERN SUN
921 SW WASHINGTON ST SUITE 160
PORTLAND OR L
97205

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85007

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142 A SKYLINE DR
GLEN MILLS PA P
19342

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LOCKHEED SOLAR TEST
B205 0-52-32 3251 HANOVER ST L
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32789

GEORGE D WEIR
D J HOWARD VOCATIONAL CENTER
1555 VALLEY MILL RD O
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WEIR & SONS
49 SCHOOL ST P
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10504

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WOLGANG WERZEL DEZIGN LTD
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CALGARY ALTA CANADA
T250A4

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1329 E ST NW ROOM 759 O
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AILBURN CA L
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90280

LYLE C WILCOX
DEAN-COLLEGE OF ENGR
CLEMSON UNIV O
CLEMSON SC
29631

LORNE WILHELM
1031 CREEK LANE
LA HABRA CA L
90631

THOMAS M WILKINSON
ASSOCIATED BROKERS
654 291/2 RD L
GRAND JUNCTION CO
81501

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GLENDALE NY P
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FONTAINEBLEY APTS D OPL
SAN ANTONIO TEXAS
78209

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CORNING GLASS WORKS
HOUGHTON PK 8 BLDG P
CORNING NY
14830

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VAN DRESSER CORP
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RONALD WILKS
LAVELLE AIRCRAFT CO
STERLING STREET P
NEWTON PA
18940

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TULLAHOMA TN
37388

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LAJET ENERGY
2964 LBJ FREEWAY SUITE 402 L
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COMMUNITY ACTION IN SELF HELP
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SODUS NY
14551

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TENN VALLEY AUTHORITY
426 UNITED BANK BLDG C
CHATTANOOGA TN
37401

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APPENDIX B

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APPENDIX C

AGENDA FOR EACH CONFERENCE

U.S. DEPARTMENT OF ENERGY'S REGIONAL SOLAR UPDATES 1979

DEARBORN, MICHIGAN
July 11 - 13, 1979
AGENDA SUMMARY

Wednesday, July 11, 1979:	4:00-8:00 pm	**REGISTRATION** - East and West Counter
	4:00-8:00 pm	**RECEPTION** - Poolside

THURSDAY, July 12, 1979	
8:00-9:00 am	**REGISTRATION** West Counter
9:00-9:20 am	**OPENING REMARKS** Springwells
9:20-9:50 am	**KEYNOTE ADDRESS** Springwells
9:50-10:10 am	**THE DEPARTMENT OF ENERGY (DOE) COMMERCIAL DEMONSTRATION PROGRAM** Springwells
10:10-10:30 am	**COFFEE BREAK** - Foyer
10:30-10:50 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD) RESIDENTIAL DEMONSTRATION PROGRAM** Springwells
10:50-11:15 am	**CODES AND STANDARDS PROGRAM** Springwells
11:15-11:35 am	**DEVELOPMENT OF STANDARDS AND TECHNICAL EVALUATION OF RATING METHODS** Springwells
11:35-12:00 noon	**QUESTIONS AND ANSWERS** Springwells
12:00-1:30 pm	**LUNCHEON** - Dearborn
1:30-3:25 pm	**THE NATIONAL SOLAR DATA PROGRAM** Springwells
3:25-3:45 pm	**COFFEE BREAK** - Foyer
3:45-5:30 pm	**THE NATIONAL SOLAR DATA PROGRAM (Continued)** Springwells
6:30-8:00 pm	**FILM PROGRAM** Stearns-Knight Suite

FRIDAY, July 13, 1979	
9:00-10:15 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT RESIDENTIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Springwells
10:15-10:35 am	**COFFEE BREAK** - Foyer
10:35-11:50 am	**THE DEPARTMENT OF ENERGY COMMERCIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Springwells
12:00-2:00 pm	**LUNCHEON** - Dearborn
2:00-3:30 pm	**CONCURRENT FEDERAL PROGRAM AND REGIONAL SOLAR ENERGY CENTER PANEL DISCUSSIONS** **FEDERAL PROGRAM PANEL** – Atlanta, Chicago, Houston and San Francisco Suites **MID-AMERICAN SOLAR ENERGY COMPLEX PANEL** – Springwells
3:30-3:45 pm	**COFFEE BREAK** - Foyer
3:45-4:45 pm	**SMALL GROUP DISCUSSIONS** Dearborn
4:45-5:00 pm	**CLOSING REMARKS** Dearborn

U.S. DEPARTMENT OF ENERGY'S REGIONAL SOLAR UPDATES 1979

ORLANDO, FLORIDA
July 15 - 17, 1979
AGENDA SUMMARY

Sunday, July 15, 1979	2:00-5:30 pm	Florida Solar Energy Center Tour (Optional)
	4:00-8:00 pm	REGISTRATION - Citrus Crown Lobby
	4:00-8:00 pm	RECEPTION - Poolside

MONDAY, JULY 16, 1979

8:00-9:00 am	REGISTRATION Citrus Crown Lobby
9:00-9:20 am	OPENING REMARKS Citrus Crown Ballroom
9:20-9:50 am	KEYNOTE ADDRESS Citrus Crown Ballroom
9:50-10:10 am	THE DEPARTMENT OF ENERGY (DOE) COMMERCIAL DEMONSTRATION PROGRAM Citrus Crown Ballroom
10:10-10:30 am	COFFEE BREAK - Exhibit Hall
10:30-10:50 am	THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD) RESIDENTIAL DEMONSTRATION PROGRAM Citrus Crown Ballroom
10:50-11:15 am	CODES AND STANDARDS PROGRAM Citrus Crown Ballroom
11:15-11:35 am	DEVELOPMENT OF STANDARDS AND TECHNICAL EVALUATION OF RATING METHODS Citrus Crown Ballroom
11:35-12:00 noon	QUESTIONS AND ANSWERS Citrus Crown Ballroom
12:00-1:30 pm	LUNCHEON - Exhibit Hall
1:30-3:25 pm	THE NATIONAL SOLAR DATA PROGRAM Citrus Crown Ballroom
3:25-3:45 pm	COFFEE BREAK — Exhibit Hall
3:45-5:30 pm	THE NATIONAL SOLAR DATA PROGRAM (Continued) Citrus Crown Ballroom
5:45-7:45 pm	Solar Office Building/Reedy Creek Utilities Company Inc. Tour (Optional)
6:30-8:00 pm	FILM PROGRAM Citrus Crown Ballroom

TUESDAY, JULY 17, 1979

9:00-9:50 am	THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT RESIDENTIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS Citrus Crown Ballroom
9:50-10:15 am	THE DEPARTMENT OF ENERGY COMMERCIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS Citrus Crown Ballroom
10:15-10:35 am	COFFEE BREAK - Exhibit Hall
10:35-11:50 am	THE DEPARTMENT OF ENERGY COMMERCIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS (Continued) Citrus Crown Ballroom
12:00-2:00 pm	LUNCHEON - Exhibit Hall
2:00-3:30 pm	CONCURRENT FEDERAL PROGRAM AND REGIONAL SOLAR ENERGY CENTER PANEL DISCUSSIONS FEDERAL PROGRAM PANEL — Orange Ballroom SOUTHERN SOLAR ENERGY CENTER PANEL — Seminole Ballroom
3:30-3:45 pm	COFFEE BREAK - Exhibit Hall
3:45-4:45 pm	SMALL GROUP DISCUSSIONS Exhibit Hall
4:45-5:00 pm	CLOSING REMARKS Exhibit Hall

U.S. DEPARTMENT OF ENERGY'S REGIONAL SOLAR UPDATES 1979

PHILADELPHIA, PENNSYLVANIA
July 29 - 31, 1979
AGENDA SUMMARY

SUNDAY, July 29, 1979: 4:00-8:00 pm REGISTRATION - Grand Ballroom North Lobby
4:00-8:00 pm RECEPTION - Brandywine Ballroom - Salon F6

MONDAY, July 30, 1979		TUESDAY, July 31, 1979	
8:00-9:00 am	**REGISTRATION** Grand Ballroom North Lobby	9:00-10:15 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT RESIDENTIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Commonwealth Ballroom
9:00-9:20 am	**OPENING REMARKS** Commonwealth Ballroom		
9:20-9:50 am	**KEYNOTE ADDRESS** Commonwealth Ballroom		
9:50-10:10 am	**THE DEPARTMENT OF ENERGY (DOE) COMMERCIAL DEMONSTRATION PROGRAM** Commonwealth Ballroom		
10:10-10:30 am	**COFFEE BREAK** - East and North Lobbies	10:15-10:35 am	**COFFEE BREAK** - East and North Lobbies
10:30-10:50 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD) RESIDENTIAL DEMONSTRATION PROGRAM** Commonwealth Ballroom	10:35-11:50 am	**THE DEPARTMENT OF ENERGY COMMERCIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Commonwealth Ballroom
10:50-11:15 am	**CODES AND STANDARDS PROGRAM** Commonwealth Ballroom		
11:15-11:35 am	**DEVELOPMENT OF STANDARDS AND TECHNICAL EVALUATION OF RATING METHODS** Commonwealth Ballroom		
11:35-12:00 noon	**QUESTIONS AND ANSWERS** Commonwealth Ballroom	12:00-2:00 pm	**LUNCHEON** - Brandywine Ballroom
12:00-1:30 pm	**LUNCHEON** - Brandywine Ballroom	2:00-3:30 pm	**CONCURRENT FEDERAL PROGRAM AND REGIONAL SOLAR ENERGY CENTER PANEL DISCUSSIONS**
1:30-3:25 pm	**THE NATIONAL SOLAR DATA PROGRAM** Commonwealth Ballroom	**FEDERAL PROGRAM PANEL** Commonwealth Ballroom Salon _ & K	**NORTHEAST SOLAR ENERGY CENTER PANEL** Commonwealth Ballroom - Salon H & J
3:25-3:45 pm	**COFFEE BREAK** - East and North Lobbies	3:30-3:45 pm	**COFFEE BREAK** - East and North Lobbies
3:45-5:30 pm	**THE NATIONAL SOLAR DATA PROGRAM (Continued)** Commonwealth Ballroom	3:45-4:45 pm	**SMALL GROUP DISCUSSIONS** Brandywine Ballroom
6:30-8:00 pm	**FILM PROGRAM** Commonwealth Ballroom	4:45-5:00 pm	**CLOSING REMARKS** Brandywine Ballroom

U.S. DEPARTMENT OF ENERGY'S REGIONAL SOLAR UPDATES 1979

LOS ANGELES, CALIFORNIA
August 1 - 3, 1979
AGENDA SUMMARY

Wednesday, August 1, 1979: 4:00-8:00 pm **REGISTRATION** - California Lounge
4:00-8:00 pm **RECEPTION** - Plaza Level

THURSDAY, August 2, 1979	
8:00-9:00 am	**REGISTRATION** California Lounge
9:00-9:20 am	**OPENING REMARKS** Beverly Hills Room
9:20-9:50 am	**KEYNOTE ADDRESS** Beverly Hills Room
9:50-10:10 am	**THE DEPARTMENT OF ENERGY (DOE) COMMERCIAL DEMONSTRATION PROGRAM** Beverly Hills Room
10:10-10:30 am	**COFFEE BREAK** - Beverly Hills Foyer
10:30-10:50 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD) RESIDENTIAL DEMONSTRATION PROGRAM** Beverly Hills Room
10:50-11:15 am	**CODES AND STANDARDS PROGRAM** Beverly Hills Room
11:15-11:35 am	**DEVELOPMENT OF STANDARDS AND TECHNICAL EVALUATION OF RATING METHODS** Beverly Hills Room
11:35-12:00 noon	**QUESTIONS AND ANSWERS** Beverly Hills Room
12:00-1:30 pm	**LUNCHEON** - Los Angeles Room
1:30-3:25 pm	**THE NATIONAL SOLAR DATA PROGRAM** Beverly Hills Room
3:25-3:45 pm	**COFFEE BREAK** - Beverly Hills Foyer
3:45-5:30 pm	**THE NATIONAL SOLAR DATA PROGRAM (Continued)** Beverly Hills Room
6:30-8:00 pm	**FILM PROGRAM** Beverly Hills Room

FRIDAY, August 3, 1979	
9:00-10:15 am	**THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT RESIDENTIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Beverly Hills Room
10:15-10:35 am	**COFFEE BREAK** - Beverly Hills Foyer
10:35-11:50 am	**THE DEPARTMENT OF ENERGY COMMERCIAL DEMONSTRATION PROJECT PAPER PRESENTATIONS** Beverly Hills Room
12:00-2:00 pm	**LUNCHEON** - Los Angeles Room
2:00-3:30 pm	**CONCURRENT FEDERAL PROGRAM AND REGIONAL SOLAR ENERGY CENTER PANEL DISCUSSIONS** **FEDERAL PROGRAM PANEL** - Beverly Hills Room **WESTERN SUN PANEL** - Santa Monica Room
3:30-3:45 pm	**COFFEE BREAK** - Beverly Hills and Santa Monica Foyers
3:45-4:45 pm	**SMALL GROUP DISCUSSIONS** Los Angeles Room
4:45-5:00 pm	**CLOSING REMARKS** Los Angeles Room

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