DEVELOPMENT OF MARKETS
FOR
SOLAR WATER HEATING SYSTEMS

FINAL REPORT

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I. INTRODUCTION

Background

CSTRR received a Financial Assistance award #DE-FC36-98G010355 from the U.S. Department of Energy (DOE) on 10/1/98 for the "Development of Markets for Solar Water Heating Systems" in response to a DOE Solicitation dated June 15, 1998. Under this Financial Assistance award, CSTRR with the support and assistance of their team partners: the Pulte Home Corporation, Nevada Power Company, Nevada State Energy Office, and the University of Nevada agreed to support DOE efforts to accelerate the establishment of markets for solar water heating (SWH) systems in order to develop a sustainable market for SWH in the residential building sector. CSTRR's initial response to this solicitation targeted the Las Vegas markets as the market of choice for this effort. Later, CSTRR submitted an Addendum to their initial proposal to include the Phoenix markets in this development process.

CSTRR's proposal to the DOE identified several reasons for the selection of the Las Vegas and Phoenix markets for this market development effort as both cities enjoy the highest solar resource of the major US cities and are among the fastest growing cities in the US with a combined residential construction of approximately 60,000 homes per year.

The CSTRR team was considered a significant plus for this effort as:

- CSTRR, a DOE/Nevada grantee, is a State of Nevada leader in promoting renewable energy and has been working to promote renewables throughout the Southwest region as well.
- Pulte Home Corporation, the largest residential homebuilder in the US at the time of this award and an industry leader in both markets, has received national recognition for its energy conservation designs in Las Vegas.
- Nevada Power Company is the primary electric utility in the Nevada market. They have an aggressive "green power" program and under this "green power" program have constructed a 25 kW, grid connected, PV power supply. Other PV generation projects are being planned.
- Nevada State Energy Office has received national recognition for its successes in working with homebuilders in the implementation of DOE and EPA renewable and energy conservation programs.
- University of Nevada professors in Las Vegas and Reno committed to the project effort are nationally recognized for their expertise in renewable energy. They were expected to use their technical expertise in the selection of the best SWH products.

SWH Heating in the Residential Market

The SWH concept reborn in the mid-seventies has undergone significant advancements under the leadership of the DOE and their predecessor agencies. Advancements have included new, improved, materials, designs, and system integration concepts. Attempts to introduce the new designs into the residential markets during the late seventies and early eighties with the aid of federal and state tax incentives were largely unsuccessful. These earlier efforts were unsuccessful for a number reasons:

Economics – Very often, installed SWH system costs did not produce a simple payback without the benefit of tax incentives. When the federal government and many of the states eliminated or reduced the tax incentives, there was no economic benefit for systems. Many of the systems sold during that period were for existing homes, which were far more expensive than systems installed on new homes. These retrofit sales were more expensive than sales for new construction due to higher marketing and installation expenses.

Aesthetics – Many of these earlier system installations did not earn rave reviews for their appearance on the roof nor in the mechanical room. Support structures, used to prop the collectors on the roof, were unsightly, collector finishes degraded rapidly, non-glass glazing deteriorated, outgassing clouded the glazings, piping and pipe insulation were unsightly. Tracking collectors were especially visible and unsightly. In the mechanical room, a myriad of pipes, valves and related equipment were assembled without concern for their appearance. Large tanks used in conjunction with the conventional hot water heater created further clutter. The end result of these violations of design and installation practices poisoned the general public attitudes toward SWH.

Performance, reliability and durability – During this explosion of SWH sales in the 70's early 80's largely due to tax credits, every imaginable SWH design was being sold, many without the benefit of rigorous testing and validation. Impossible performance claims were made and promises of 10, 20 and 30 year lifetimes were common without the benefit of test data to support the claims. Not unexpectedly the claims were never realized, as the promised quantities of hot water were not delivered. Some systems simply didn't work due to improper designs, other systems performed poorly due to faulty installations, and the performance of other systems disintegrated rapidly due to failed components or simply the disintegration of materials and or scaling. Tracking collectors simply quit tracking.

System Installations – As noted, many of the above problems were caused by improper installations. Often, untrained installers were used and final installation inspections were not performed. When problems did occur, the homeowner was often not aware that the system had failed. When system problems were reported, service organizations were not trained to repair the systems.

Codes and Standards – During this rebirth period, SWH system codes and standards were in the early stages of development. Testing protocols were being written and as stated above, many systems had not been properly tested and therefore performance claims could not be substantiated. Local building officials contributed to the difficulties as many building codes were so restrictive and building permits so bureaucratic and time consuming that many solar firms simply ignored the permitting process. The combined impacts of these code and

standard deficiencies further contributed to system installations that didn't meet minimum design and/or installation principles.

Financing – Financing of SWH systems is a serious issue given the typical sales price of several thousand dollars. The new homebuyer can include this cost in the home mortgage and use the energy savings to partially offset the increased mortgage payment. However, cost containment is a necessity with many buyers given the buyer's mortgage qualification limits. A qualification-limited buyer must choose between the SWH option and other options e.g., flooring and countertop upgrades, energy efficient windows, fireplaces, security systems, etc. In these circumstances SWH is the likely loser.

The DOE and the solar community are fully aware of the above issues and proposals responding to the solicitation were expected to be structured to address each of the above issues. CSTRR and their partners launched their best efforts to market SWH systems in the markets approved by the DOE. The results were far less than envisioned. This report is intended to describe the activities conducted under this Financial Agreement and identifies the basis for their inability to penetrate the new residential market of Las Vegas and Phoenix thereby failing to meet the goals and objectives as planned.

II. CONCLUSIONS

Conclusion #1

In today's energy climate in this country, there is insufficient consumer motivation for the purchase of high quality SWH products when the consumer is forced to choose between the SWH appliance and more interesting home upgrades. With a limited budget and faced with a choice, the consumer will choose tile and/or carpet upgrades, better countertops, fireplaces, etc. and not solar water heaters.

- In an ideal situation, CSTRR's team attempted to create a market for SWH and was unable to successfully promote the product.
 - CSTRR's team included the nation's #1 home builder led by a visionary Director of Construction who has successfully lead the design, construction and marketing of some of the most energy efficient homes in Las Vegas and the nation. The Nevada Power Company, Nevada's largest electric utility; the Nevada State Energy Office; and two leading solar engineers from the University of Nevada joined CSTRR in this endeavor.
 - The marketplaces for this effort included two dynamic residential construction markets – Las Vegas and Phoenix.
 - CSTRR's team, after conducting extensive "due diligence" studies, selected two of the best SWH systems being produced.
- The economic and environmental advantages of the SWH option which displaces plentiful and cheap natural gas was not sufficient to create consumer interest.
- Despite widespread concerns for the environment, the consumer was not willing to pay for this "green power" alternative.

Conclusion #2

When the energy again becomes a national concern as it was in the mid-70's and the consumer revisits the renewable alternative for residences as it did then, new residential construction will be the place to create the large-scale adoption of SWH. This market pre-condition doesn't exist today and the sale of SWH is facing insurmountable odds.

- Large homebuilders, e.g., Pulte Homes, are ideally positioned to install and sell SWH at the most favorable pricing as they are able to obtain the best product pricing, manage the installation process, minimize installation and sales expenses, and provide warranty coverage.
- Homebuilders have the added advantage that they are better prepared to address the permitting process than is the small solar entrepreneur.
- Homebuilders exercise great care in the product selection as evidenced by Pulte's active participation in the visits to the leading SWH manufacturers and in other due diligence activities under this initiative.

Conclusion #3

Builder interests exist for new renewable energy options provided it makes sense and can compete with other consumer interests.

- During the course of this project, several builders expressed an eagerness to replicate Pulte Homes in the sale of SWH if it had been successful. When it didn't work, they quickly lost interest.
- The Summerlin Corporation, Las Vegas's largest developer, also expressed an interest in participating until the Pulte venture didn't work.

Conclusion #4

Aesthetics and product simplicity are very important and of greater importance than performance. If higher performing SWH systems, such as the indirect systems are to be accepted, their designs will have to approach the simplicity of the integrated collector/storage (ICS) configuration.

- Despite the proven performance advantages of the indirect design, Pulte's installers, supervision, and sales staff and ultimately management, preferred the simplicity and ease of installation of the ICS design.
- The issue of performance losses in the ICS designs due to higher than normal morning hot water use was not as great a concern as the collector's appearance on the roof or the visible plumbing system components at the main water heater in the garage.

Conclusion #5

Builders will need responsible supervision and inspection staff to oversee the installation process particularly for the more complex designs, such as the indirect SWH system.

- Installer training is adequate, but inadequately documented, to ensure a quality installation if procedures are followed.
- Numerous mistakes made in the installation of the more efficient indirect system design are cause for concern.
- Plumbers haven't changed since the birth of SWH – they still incorrectly install mixing valves, reverse collector connections, improperly insulate pipes, etc.

Conclusion #6

The SWH industry has demonstrated an ability to design and produce reliable and durable products supported with adequate documentation and training materials. The missing ingredient is a market.

- Both products used in this project, and those not selected, were of the highest quality and with proper installation will meet all expectations for performance, reliability and durability.
- All six manufacturers visited during the due diligence phase of this project had good manufacturing and quality controls and would be acceptable to any builder.
- The SRCC certification system has been effective in its oversight of the SWH industry.

III. PROJECT PLAN

Overview

CSTRR's SWH program was structured to provide the maximum potential for success in the introduction of SWH in new residential markets. CSTRR assembled an outstanding team and the best products produced by responsible manufacturers. To further assure success, CSTRR's plan included a rigorous due diligence process that provided for product selection based on economics and testing as necessary to confirm performance, reliability and durability when applied in the Las Vegas and Phoenix markets.

In this effort CSTRR targeted Las Vegas, NV. and Phoenix, AZ, as these cities are blessed with the highest levels of solar insolation in the U.S. and are enjoying explosive growth rates. Las Vegas is the fastest growing city in the U.S. with an annual construction of over 20,000 new residential homes. Phoenix's percentage growth is lower than Las Vegas, but the number of new homes is greater at 34,000 new homes per year. To further enhance CSTRR's potential for success, CSTRR selected the best possible team to implement this program. The team included:

Pulte Home Corporation – then the largest homebuilder in the U.S. and a nationally recognized leader in the design and construction of energy conscious homes. The Pulte Home Corp. has received numerous awards from the DOE and EPA for their designs.

Nevada Power Company – the largest electric utility in the State of Nevada and an energy conscious utility with an active "green power" program.

University of Nevada, Las Vegas and University of Nevada, Reno – Professors at both universities are nationally recognized solar experts and eminently qualified to provide technical guidance in the selection and validation of the SWH systems.

Nevada State Energy Office – This office has aggressively supported the development of energy conscious homes and renewable initiatives throughout the state.

In recognition of the issues listed above, CSTRR defined a unique set of conditions, which were needed to achieve success beginning with an interested and involved major homebuilder. Plans included:

- Selection of solar hot water products with proven performance, reliability and durability supported by test data taken in accordance with industry procedures. This test data was needed to provide assurance that the products meet or exceed consumer expectations for value, reliability, long-term and durability.
- Performance validation using in-service testing to confirm performance expectations.
- Product integration into the building envelope at the time of construction to reduce installation expenses, minimize installation issues and achieve a more aesthetically pleasing product.
- Product installation and service using a properly trained team.

- Resolution of any building code or standard barriers, which would inhibit or slow the permitting process.
- Maximizing product value through quantity purchasing.
- Use of favorable financing concepts and application of tax credits where applicable.
- Preparation and Implementation of a business and marketing plan using trained and experienced marketing staff, supported with on-site displays and point of sale information. Continually modifying and updating the market program guided by focus group studies, exit interviews and staff interviews.

As an adjunct to the Pulte Home SWH initiative, CSTRR also recognized the need to expand the SWH program to include other local and regional builders. To make this happen, an outreach program was considered necessary.

In order to implement the program concepts listed above, CSTRR identified five major tasks for this program:

Task 1 – Business Planning

Under this task, a comprehensive SWH product and manufacturer assessment was conducted based on a set of prescribed selection criteria to assure the selection of the best product with a manufacturer fully qualified to meet Pulte Homes' partnership criteria. As part of the selection process, the CSTRR solar experts were expected to prepare and approve the selection criteria and with the participation of all members of the CSTRR team conduct on-site reviews of the leading systems. All performance, reliability and/or durability issues were to be resolved through independent testing. Economic returns for the candidate designs and products were to be confirmed using industry accepted analyses.

Task 2 – Market Assessments

Prior to the initiation of a Pilot Program, a preliminary market assessment was to be conducted by Pulte Homes to identify the appropriate price range for the SWH product and the most appropriate subdivisions for the installation and sale of the product. During this phase, preliminary architectural and mechanical designs were to be completed and retail product pricing to be established based on product cost, installation and marketing expenses and builder markups.

Task 3 – Market and Business Development Planning

A detailed Market and Business Development Plan was to be prepared. This plan was expected to define a marketing program best suited to the introduction and marketing of the SWH product in order to achieve 1999/2000 and 5-year sales goals. This plan was to include: 1) strategies and plans for the resolution of all product and marketing issues, 2) plans for properly training the installation and tract sales staff, 3) warranty policies, 4) Pilot Program plans for the design, installation, marketing and marketing program evaluations, and 5) financing incentives to enhance the economics of the installed product to increase market penetration.

Task 4 – Pilot Program Implementation

Under this task, Pulte Homes was expected to install six systems in model homes in two different subdivisions in the Las Vegas market and 3 systems in model homes in a single Phoenix subdivision. Prior to the model home installations, the training programs were to be conducted for the installers, supervision, and inspectors. Upon completion of the model home installations, training programs were to be held with the sales staff.

Task 5 – Pilot Program Evaluation

This task was designed to: 1) confirm product performance, 2) adequacy of the training programs, 3) consumer acceptance of the product, and 4) identify any issues with any aspect of the program. Also under this task, a thorough in-service product test program was planned and builder and focus group studies were to be used to assess perceptions regarding the product and consumer attitudes. Based on these studies further refinements in the marketing program were expected.

IV. PROJECT GOALS and OBJECTIVES

OBJECTIVES

The objective of the SWH initiative was to introduce the SWH product into the new, residential construction market thereby increasing the awareness of the homebuilder, homebuyer and the general public to the benefits of SWH.

GOALS

1999/2000 Goals

Design and install six SWH systems in model homes at two Las Vegas subdivisions and two SWH systems at one Phoenix subdivision. Twenty and ten retail systems will be sold during 1999 in Las Vegas and Phoenix, respectively. Pulte's successes with the sale of SWH systems will result in the adoption of the SWH product by other production builders in both markets.

Five-Year Goals

Within five years, with confirmation of the SWH performance, Pulte Homes expects sales will exceed 5000 SWH units with annual sales of 2000 units per year by the fifth year.

V. FINDINGS

Task 1 – Business Planning

Background

Before initiating the product selection process, a product selection criteria document was prepared by CSTRR's technical advisors. In accordance with these criteria, all products were required to have OG-300 certification for solar hot water systems from the Solar Rating and Certification Corporation (SRCC), an independent third party certification organization representing the solar industry. SRCC certification is performed for the industry under the auspices of the Florida Solar Energy Center (FSEC) located in Cocoa Beach, Florida. This certification addresses system design, installation, and operation and maintenance (O & M) documentation.

In addition to assurances of product certification, the selection criteria assessed the degree of installation difficulty and cost of the system. In this regard the team considered the quality and completeness of system integration on the roof and in the mechanical room. Pulte insisted that the plumbing systems had to be completely integrated and easily installed. The availability of product installation/service documentation was as essential as a clean aesthetically pleasing installation. Warranty policies dictated in the SRCC certification process were required. System pricing had to meet minimum standards to satisfy the retail pricing goals of this project.

These criteria also assessed the manufacturer's quality control systems, their ability to satisfy planned production, and their financial resources. The SWH Selection Criteria and SRCC technical factors used for these assessments are provided in Appendices A and B.

Using these criteria and the SRCC ratings handbook, CSTRR's technical advisors and Pulte Homes staff considered the four types of SWH systems that are SRCC certified:

Forced Circulation or "active" systems - use pumps with and without heat exchangers to circulate water or antifreeze solutions as a means of transferring solar heat from the collector to the potable water storage tanks.

Integral Collector Storage (ICS) systems - "batch" water heaters using the solar collector serves a dual function as a solar heat absorber and hot water storage holding tank. These ICS systems are normally connected in series with the conventional home water heater.

Thermosyphon systems - roof mounted tanks that store solar heated water on the roof. Tanks are located above the collector such that natural thermal convection can be used to transfer solar heat from the collector into the storage tank. As with the ICS design the storage tank is connected in series with the conventional water heater.

Self-Pumping systems - utilize the phase change of a liquid-vapor medium to transfer solar energy from the collector into the storage.

Based on preliminary evaluations and discussions, it was decided to limit the system design choices to the forced circulation and ICS designs. The thermosyphon and self-pumping designs were

eliminated from considerations by Pulte Homes, as they did not provide a clean, unobtrusive and integrated, appearance.

Two versions of the forced circulation concept were considered. The first was an anti-freeze design in which the solar radiation heats an anti-freeze solution in the collector with a heat exchanger being used to transfer this energy into the conventional water heater. This design has been used extensively, particularly in regions where excessive freezing can occur. A review of historic records for Las Vegas revealed temperature extremes of +8 °F occurred on two occasions in 1937 and 1963 with fairly common occurrences of temperatures in the teens. Given the potential for these freeze conditions, the forced circulation selection was considered to be an appropriate choice.

The second forced circulation concept considered by the technical advisors was a "drainback" configuration in which water is used to collect solar energy and transfer this energy to the conventional water heater. In this design, the collector water usually drains into a separate holding tank when the collector is not operating so that freezing temperatures can be tolerated. Single fluid and two fluid designs are produced. In the single fluid design, potable water from the conventional hot water heater is used in the collector. In a two fluid system, collector water is separate from the potable water with heat transferred into the conventional tank via a heat exchanger.

After a review of SRCC approved ICS and forced circulation systems, a list of five manufacturers was identified for further consideration including:

- Heliodyne, Inc. – Indirect, anti-freeze, forced circulation system
- Radco Products – Indirect, drainback, forced circulation system
- SunEarth, Inc. – ICS system and the indirect, drainback, forced circulation system
- Sun Systems, Inc. – ICS system
- Thermal Conversion Technology – ICS system

Site visits were made to each of the above manufacturers by the CSTRR team to inspect the finished products, manufacturer quality controls, discuss issues with the manufacturers and witness actual residential installations. The site visit representatives included CSTRR's technical consultants, the Pulte Home Director of Construction and a technical representative from the Nevada Power Company. It was generally concluded that these on-site visits provided significant information and confidence that the manufacturers had the resources to meet the planned production goals of the program. After completing these site visits, an overview of the observations was prepared (Appendix C). The results of these observations and a comparison of SRCC published performance data dated September 1998 (Appendix D) resulted in a Pulte Homes decision to eliminate the drainback design from further consideration as the benefits were not sufficient to offset the added complexity of the design and installation.

After completing the site surveys, performance and economic analyses were conducted and reliability/durability and other issues were resolved for the remaining candidate systems.

Performance and Economic Analysis

Performance studies were based on anticipated operating conditions for the Las Vegas and Phoenix markets. SRCC analysis models were used for the performance studies and a range of collector/storage configurations were analyzed for the products under consideration. The Florida Solar Energy Center was selected to perform these analyses as they manage the SRCC program and had the necessary SRCC analysis programs. TMY solar and weather data was used.

Auxiliary gas water heaters are used by Pulte Homes in the markets being considered for this program and the standard water heater size is 50 gallons. In consideration of a possible use of the Heliodyne system in an all-electric application in which the water heater would also serve as the source of heat for home heating (another Pulte Home concept), 65 and 75-gallon auxiliary water heaters were also analyzed. The Heliodyne system was not intended for the Phoenix market and therefore the analysis of this system was limited to Las Vegas.

Combinations of Heliodyne collector sizes and storage tank capacities used in these analyses were as follows:

- 3X8 Collector and (1) 65 Gal Aux Tank
- 4X8 Collector and (1) 65 Gal Aux Tank
- 3X8 Collector and (1) 50 Gal Aux Tank
- 3X8 Collector and (2) 50 Gal Aux Tanks
- 4X8 Collector and (1) 75 Gal Aux Tank
- 4X8 Collector and (1) each 50 & 75 Gal Tanks

In the analysis of the ICS designs, auxiliary water heater sizes were limited to 50 gallons. An issue unique to the ICS design is the potential for reduced efficiencies due to, heavy, early morning water draw profiles before the ICS system can produce solar heated water. To examine this issue a weighted morning water draw profile was analyzed and compared to the more balanced SRCC draw profile. The morning draw profile used in the analysis was extracted by the SRCC engineers from an earlier DOE funded study.

Best available gas and electric water heater efficiencies were assumed in the analyses. Storage tank efficiencies varied depending on the tank size. The values used in the analyses were as follows:

Auxiliary HW Tank Efficiencies Used in the Analysis

	<u>Electric (%)</u>	<u>Gas (%)</u>
50 Gal Water Heater	89.5	62.5
65 Gal Water Heater	87.9	
75 Gal Water Heater		55.3

Pulte Homes decided to restrict installations on the front of any residence. Therefore, in order to accommodate collector installations on all homes, some installations on east or west facing roofs would be necessary. Therefore, orientations of 30, 60 and 90 degrees from due south were analyzed

in addition to south facing orientations. The performance analyses were all conducted for the planned 5/12 roof pitch used by Pulte Homes in Las Vegas and Phoenix.

A complete description of the analysis plan with all the parameters is presented in Appendix E. FSEC reports for the four systems under consideration are provided in Appendices F, G, H, and I. SRCC approved models for gas and electric auxiliary use are included in these reports.

System economics was calculated for both gas and electric auxiliary installations based on the SRCC performance analyses using local gas and electric utility rates. The utility rates for Las Vegas and Phoenix are as follows:

Utility Rates (including taxes) – Electric and Natural Gas

	<u>Las Vegas</u>	<u>Phoenix</u>
Electric – (\$/kW-hr)	\$0.0647	\$0.092 (summer) \$0.0796 (winter)
Gas – (\$/mmbtu)	\$6.27	\$8.36

The economic analyses were used to compare the SWH option to conventional water heaters as shown in the table below where the auxiliary energy costs for each system is listed. It should be noted that the SWH for a typical family of four could expect an annual savings of about \$50-64 when using an ICS SWH system with a gas auxiliary water heater in Las Vegas. An additional \$10 savings will be realized in Phoenix generally due to higher gas prices. The double glazed Thermal Conversion Technology (TCT) system outperformed the other two single glazed designs.

The economic benefits of the ICS SWH system more than doubled when used with electric water heaters due to the higher costs of electric power compared to natural gas rates. Economic savings for the Heliodyne system were considerably better when used in combination with electric water heaters and marginally better when used in combination with gas water heaters. The auxiliary energy expenses as provided from these analyses are tabulated below:

Auxiliary Energy Expense – (with and w/o SWH)

	<u>Electric Auxiliary</u>		<u>Gas Auxiliary</u>	
	<u>Las Vegas</u>	<u>Phoenix</u>	<u>Las Vegas</u>	<u>Phoenix</u>
<u>No SWH System</u>	\$222	\$271	\$105	\$140
<u>ICS System</u>				
Sun Systems Sys	\$106	\$140	\$ 55	\$ 65
Sun Earth Sys	\$ 95	\$128	\$ 50	\$ 58
TCT Sys	\$ 75	\$ 99	\$ 41	\$ 46
<u>Indirect System</u>				
Heliodyne Sys	\$ 29		\$ 42	

This analysis also suggests that a decrease in system economics can be expected for ICS systems when the hot water load is skewed towards heavier morning use. Less favorable economics is the

result of increased energy losses from the exposed collector during nighttime hours. The economic penalty of the heavier morning hot water load varied from 12 to 38% depending on the design, the auxiliary energy being used and the city. The water use profile will have very little impact on indirect designs and therefore this case was not analyzed. A summary of the performance reductions for the three system designs is presented below.

ICS Performance Reductions w/Heavy Morning HW Loads

	<u>Electric Auxiliary</u>		<u>Gas Auxiliary</u>	
	<u>Las Vegas</u>	<u>Phoenix</u>	<u>Las Vegas</u>	<u>Phoenix</u>
<u>ICS Design</u>				
Sun Systems Sys	22%	21%	26%	38%
Sun Earth Sys	17%	17%	16%	17%
TCT Sys	14%	13%	12%	15%

Indirect Design

Heliodyne Sys

Minimal Impact expected and not analyzed

As noted above, the opportunity to use SWH systems on all houses in any subdivision would necessitate orientations on east and west facing roofs. For this reason, the analyses included an investigation of the reductions in energy savings with collectors having east or west exposure. These analyses were encouraging as the reductions in energy delivered were only 13 to 18%. This small penalty was considered acceptable and therefore nearly all homes are candidates for installations. The energy losses for the four candidate systems in the Las Vegas and Phoenix markets is as described below:

%Reduction – Installation on East or West Facing Roof

	<u>Electric Auxiliary</u>		<u>Gas Auxiliary</u>	
	<u>Las Vegas</u>	<u>Phoenix</u>	<u>Las Vegas</u>	<u>Phoenix</u>
<u>ICS Design</u>				
Sun Systems Sys	14%	15%	13%	14%
Sun Earth Sys	15%	16%	15%	15%
TCT Sys	15%	15%	15%	15%

Indirect Design

Heliodyne Sys

15%

18%

Reliability, Durability and Other Issues

During the early planning phases of this program, the CSTRR team examined performance and economics related issues for the two ICS and Indirect system designs under consideration. Concerns with the indirect design were: 1) system reliability - given the large number system components subject to possible wear and failure, 2) replacement cost of potential failure items, 3) limited life and impacts of the anti-freeze solution particularly under prolonged stagnation conditions, 4) system complexity, and 5) general appearance of the finished product.

In the ICS system with tap water in the collector the concerns were: 1) freezing potential under extreme conditions which could interrupt the water supply to the residence or cause pipe failure and leaks, 2) possible scaling or pitting corrosion in sites having water with excessive mineral or alkali content, and 3) possible roof damage due to the weight of a full collector.

Given the limited resources of this program, every effort was made to resolve these issues without incurring unacceptable expenses. Through consultation with the manufacturers and industry experts, satisfactory conclusions to most issues, with the exception of the ICS freeze issue, were satisfactorily resolved without resorting to special tests.

Resolution of Indirect System Issues

In examining the component reliability and replacement cost issue for Heliodyne's Indirect design, industry studies were reviewed and Heliodyne engineers and DOE laboratory personnel were consulted to identify the potential failure items in the system and to assess industry experiences with the failure of the system components. The items most often cited for possible failure were:

- Anti-freeze solutions – depletion of the inhibitors occurring with time of use and overheating.
- Pumps – wear which can be exacerbated by improper installation, excessive temperatures, loss of fluid or entrained air
- Controller and/or sensors – typical component mean time to failure possibly exacerbated by electrical transients including lightning strikes.
- Expansion tanks – normal deterioration exacerbated by excessive overheating
- Valves – most probably the vent valve, mixing valve or check valve
- Pipe insulation – particularly insulation exposed to direct sunlight
- Collectors – absorber leaks or plugging caused by anti-freeze problems, connector leaks, glazing breakage or weathering of the exposed materials

A serious issue with the indirect design is the lifetime, system maintenance cost, reliability and durability of the propylene glycol based anti-freeze used in the Heliodyne systems. According to the manufacturers data and discussions with Dow Chemical engineers, inhibitors in the propylene glycol will be depleted causing the solution to become acidic. Once it becomes acidic, corrosion will occur causing the formation of sludge and increasing the potential for leaks. This problem is exacerbated by prolonged overheating above 325 °F which causes acceleration in the loss of inhibitors. The Heliodyne collector is capable of exceeding this temperature under stagnation conditions, which could occur if the homeowner were not able to use all the heat produced. It is anticipated that the only times this would occur would be in the event of a system failure or when the homeowner was absent from their home for more than a few days.

Under normal conditions, the glycol solutions are likely to remain in a healthy condition for 7-10 years. Over this time interval the inhibitors will gradually be depleted and must be replaced or the entire solution must be replaced, a very simple procedure. The amount of fluid in the system has a value of about \$50. Several steps have been taken to optimize the fluid lifetime. The first step was to limit the system size such that the typical resident will use all the hot water produced except when not home for several days. The second and most important step was the selection of the best available glycol. According to DOW engineers, their DowFrost HD provides the best chemical stability and the highest stagnation temperature protection. A final step was the use of distilled water when mixing the glycol solution as ordinary tap water contains iron and minerals, which increase the potential for sludge formation. Heliodyne, the supplier of the indirect system provided a pre-mixed anti-freeze solution using distilled water.

The next most costly replacement item is the pumps and the Heliodyne system selected this project has two pumps. One pump circulates the anti-freeze solution through the collector and the second pump circulates fresh water through a heat exchanger thereby transferring heat from the collector fluid into the residential hot water tank. Relying on industry experience, it was concluded that under normal operating conditions, these pumps should have a mean time to failure of 8-10 years.

Failure experiences with other Heliodyne system components suggest failure rates should not be less than 10 years. Collectors, the most expensive system item, are expected to have a lifetime of 20+ years.

The replacement cost of the system components can be significant if performed individually as failures occur. However, these costs can be mitigated with proper maintenance procedures. For example, if a pump were to fail under normal conditions, consideration should be given to the replacement of both pumps, the anti-freeze or any other component with evidence of wear. Using this approach it should be possible to limit the normal maintenance to periods of 5-10 years.

In consultation with Heliodyne engineers, it was concluded that additional relief from the maintenance issue could be achieved through the adoption of their newest system design. In this design the number of components in the mechanical room are reduced through the use of: 1) a photovoltaic (PV) powered pump that is located on the roof with a small PV panel, 2) a thermosyphon heat exchange design for the transfer of heat from the collector heat transfer fluid into the fresh water supply in the conventional water heater, 3) a mechanical pump for purging air during the installation and maintenance of the system. With these changes, one pump, the controller/sensor, and a vent valve are eliminated.

This newer Heliodyne design will also reduce the overall complexity of the unit in the mechanical room. The current configuration was considered to be unacceptable to Pulte installers and sales staff due to the use of (2) pumps, a controller, expansion tank, heat exchanger and various valves. Some of Pulte's sales staff was concerned that the potential client may be overwhelmed by the appearance of the finished product. Although the newer Heliodyne design reduces the complexity and improves the appearance, the advantages of this design was not evaluated since no additional Heliodyne systems were installed.

The problems with the roof-mounted equipment were the collector attachments, the appearance of the exposed piping and insulation, and the prominence of the vent valve. Pulte designs placed the collector at the bottom of the roof using 90# felt under the collector. The felt was extended beyond the collector to the bottom of the roofline further detracting from the general appearance since the tile

did not completely surround the collector. Piping was not optimally installed and the vent valve was very visible. Pipe insulation further detracted from the overall appearance on the roof.

A much cleaner collector installation can be achieved through the addition of a sheet metal pan under the collector, as with the ICS design. This sheet metal pan would be used to collect any rainwater or leaking collector fluids and direct these fluids over the tile thus eliminating the need for the placement of 90# felt under the collector. With this change the collector could be placed at the ridgeline of the residence and the tile can abut the collector thus providing a very clean installation as with the ICS design. Further improvements on the roof could be gained with minor redesign of the collector plumbing that would allow the collector piping to penetrate the roof immediately as they leave the collector. With this modification, very little plumbing would be exposed and therefore very little insulation as well.

The PV powered pump design will greatly simplify the equipment needed in the mechanical room, as the collector pump would now be located on the roof. No controller would be required. The only visible components in the mechanical room would be a heat exchanger, expansion tank, the mixing valve, and check valve.

In summary, it is concluded that aesthetics, installation and maintenance issues with Heliodyne's indirect design as used in this project were legitimate concerns due to the added installation problems, increased operation and maintenance expenses, increased complexity, and generally undesirable appearance of the installed product. However, in future installations these negatives would be mitigated through the adoption of the newer Heliodyne design and other design changes as described above.

Resolution of the ICS Design Issues

While the ICS system had none of the indirect design concerns, its design raised other questions, which had to be answered. In this design the collector/storage combination, located on the roof, is susceptible to freezing. The lowest recorded temperatures in Las Vegas were 8 °F (winters of 1937 and 1963 and more recently 12.8 °F recorded in 1990).

To assess the tolerance of the ICS design to these extreme temperature conditions, it was decided to conduct a test program to evaluate the design tolerance through simulation of a typical temperature profiles which might occur on low temperature days. A cold chamber at the Nevada Test Site (NTS) was used for these tests. A test fixture was constructed and a Sun Systems, Inc. collector was instrumented with thermocouples. Hourly temperatures in the cold chamber were programmed to simulate the expected hourly temperature profile experienced during the extreme low temperature conditions, which occurred in Las Vegas in 1937 and 1963. The only hourly temperature profile available during extreme low conditions was for Dec. 22/23, 1990 on which the lowest temperature was 12.8 °F and so this temperature profile was extrapolated for the test.

These tests confirmed the vulnerability of exposed piping to freezing under extreme conditions, as exposed insulated piping froze solid within a few hours. These tests also demonstrated that internal components are only marginally acceptable as the large 4" collector tubes inside the collector turned to slush by the end of the cold cycle. Fortunately, the inlet and outlet connections in the Sun Systems collector design are not exposed. The other two ICS designs under consideration for this program have exposed pipe connections on the roof and would not be acceptable without trace heaters. The final report for the freeze test program is provided in appendix J.

A second issue with the ICS design was the potential for scaling or corrosion from water supplies having excessive mineral content or alkalinity. This issue was discussed with the City of Las Vegas water department. They confirmed that all new developments in Las Vegas are served by water from the Lake Mead reservoir and have acceptable levels of mineral content. In Phoenix we were advised that some residences served with well water have excessive mineral content and are susceptible to severe scaling, but water used by the Pulte subdivision selected for this project has acceptable water for an ICS collector. DOE's Sandia laboratory experts confirmed that the scaling issue should not be a problem. Complete confidence in the water quality issue would have required water sampling and testing coupled with extensive scale testing. This effort was beyond the scope of this program and the opinions of the DOE laboratory personnel were accepted.

The third and final issue with the ICS design is the system weight, which could impact the structural integrity of the home. A filled collector weighs approximately 600 lbs. Pulte Home structural engineers concluded that some additional, but minor, bracing is sufficient to resolve this issue. This is easily accomplished in new home construction. This weight issue would present a more difficult problem in retrofit situations.

Conclusions

Upon completion of the analyses and investigation of the maintenance, reliability and durability issues, the conclusions reached by CSTRR's technical advisors was that the ICS system manufactured by Sun Systems, Inc. and indirect system manufactured by Heliodyne Inc. are acceptable for Pulte Home use in the Las Vegas and Phoenix markets. The selection of the "best" design is ambiguous at best as both designs have their positive and negative characteristics.

The ICS design is attractive because of its inherent simplicity. It has no moving parts and serves as an effective pre-heater for the conventional water heater. The concerns with this design is its sensitivity to homeowner hot water use profiles, possible corrosion when exposed to poor water supplies and possible freezing at the worst recorded weather conditions in Las Vegas. Low temperatures in Phoenix are not a concern. Performance analyses conducted by SRCC engineers confirmed that a heavy morning hot water user could experience as much as a 20-30 % reduction in solar heated hot water when compared to the typical hot water user. Therefore, Pulte Homes was advised that they might wish to pre-qualify the buyers for this design based on their anticipated hot water use patterns.

The water quality issue with the ICS design requires local water sampling to ensure the absence of any unusual mineral content that might cause scaling or corrosion. Except in very limited areas not served by the Las Vegas Water District and not considered for construction by Pulte Homes, water quality should not be a problem.

The indirect design manufactured by Heliodyne, Inc. was also considered a good choice for this project. Performance analyses and experience has demonstrated that this SWH system will outperform the ICS design but at the expense of added complexity and increased maintenance costs due to the limited life of the pumps, controllers, other components and the anti-freeze solution. The pumps are expected to have an 8-10 year lifetime and the anti-freeze must be changed on average every 7-10 years. It should be noted that the simultaneous replacement of the pumps (2) and anti-freeze could result in a \$250-\$300 maintenance cost. An unresolved issue with the anti-freeze is the

impact of prolonged stagnation, which could occur during the summer months if a homeowner were to take an extended vacation.

Recommendation Presented to Pulte Homes and Selections

After considering all the information gained during the investigations during this program and after consulting with DOE laboratory personnel, CSTRR's technical advisors recommended both designs.

Task 2 – Market Assessments

Background

In this phase of the program, Pulte was expected to conduct an analysis of the residential buyer for the purposes of selecting the optimal locations and residential product price ranges for the introduction of SWH into the Las Vegas and Phoenix markets. Pulte Homes' management were also expected to review CSTRR's SWH recommendations, make their final selections, and complete business agreements with the selected manufacturers. Retail pricing for the installed product was then expected to be established based on the installed system cost.

Product Selection

Acting on CSTRR's recommendations, Pulte management negotiated system pricing from the three ICS system manufacturers and Heliodyne, Inc. the manufacturer of the only indirect system considered for this program. Pulte's final selection was based on CSTRR's recommendations, product pricing and other factors including:

- Product quality - completed collector assembly and integrated plumbing assembly
- Installation – quality of the installation design, hardware and procedures.
- Aesthetics - general appearance of the installed product as evidenced by inspecting completely installed systems during the on-site tours to the manufacturers facilities.
- Manufacturing processes and quality control.
- Product documentation – operation and maintenance manuals, training materials, sales materials and manufacturer interest in supporting Pulte in refining these materials as required.
- Manufacturer training and sales programs – also, perceived interest in supporting these activities.

After considering all factors, Pulte management elected to proceed with the Sun Systems, Inc. ICS design and the Heliodyne, Inc. indirect design for the Las Vegas market. Given the more favorable temperature extremes in Phoenix, Pulte decided to use only the ICS design in the Phoenix market.

One of the defining factors in selecting the Sun Systems, Inc. system was their thoughtfully engineered installation concept and hardware. It also was the only ICS design that did not have

exposed piping on the roof. This was a very key factor, as the freeze testing had clearly shown that exposed piping would freeze in Las Vegas unless protected with trace heaters and this was not considered to be a viable option. Sun Systems, Inc. installation concept with their use of a sheet metal pan was also beneficial as this permitted the installation of the collector at the ridgeline. With the elimination of any piping on the roof and the installation pan, Pulte roofers were able to completely surround the collector with tile thereby creating the appearance of a skylight.

Standard Pulte practices were used to negotiate and purchase the products. Price quotes were based on (6) unit pallet pricing. Generally, these prices were comparable to distributor prices and more favorable than retail outlet pricing. Pulte received assurances that additional price reductions could be expected for quantity purchases. Understandably, at this phase of the program Pulte was not able to purchase more than a single pallet from either manufacturer and a single pallet of (6) collectors was purchased from each for the Las Vegas market. Since Sun Systems, Inc. is located in Phoenix and only one subdivision was to be test marketed, it was not necessary to purchase a complete pallet to satisfy those installations.

Retail pricing for the installed product was established based on system pricing, estimated installation expenses, estimated warranty expenses and Pulte's standard profit markup. Both systems were priced at \$2400 exceeding CSTRR's anticipated retail estimates of \$1800 to \$2000.

Market Selection

The plan presented in CSTRR's proposal for Financial Assistance Agreement specified the construction of six SWH model homes in two subdivisions in Las Vegas and three SWH model homes in a single subdivision in Phoenix. In an agreement with the Nevada Power Company, a CSTRR partner in this project, in each of the Las Vegas subdivisions, there was to be one SWH system supplied with a conventional gas water heater, one SWH system supplied with a conventional electric water heater and one SWH system in an all-electric home (later dropped). In Phoenix all SWH systems were to be supplied with gas water heaters.

Pulte construction and marketing staff, relying on their homebuyer experience, determined that the SWH purchaser would most likely be a young professional family household with some discretionary funds and therefore not seriously constrained by mortgage qualification limits. This purchaser would also be most likely to be environmentally and energy sensitive. Given these expectations, Pulte selected two subdivisions in the Las Vegas area. Homes in one of these subdivisions were in the upper-end price range for Las Vegas, 2500-3000 sq. ft. in size and priced in the low \$200,000's. The second subdivision was in the move-up price range, 1800-2500 sq. ft. and priced from \$150,000-\$180,000.

One subdivision, Crown Ridge, was located in Summerlin, the nationally recognized and largest master planned community in Las Vegas, located in northwest Las Vegas. The second Las Vegas site, Pulte's Stallion Mountain subdivision, is a newly developed 700 home subdivision located in southeast Las Vegas.

Task 3 – Market and Business Development Planning

Background

Under this task, CSTRR with the support of Pulte Homes, Nevada Power Company and the State of Nevada Energy Office planned to develop a marketing strategy for the introduction of SWH in the greater Las Vegas and Phoenix markets. A marketing and business plan was to be developed with five-year market projections for Pulte sales. In concert with this market plan, a broader outreach plan was to be developed to expand the program to include other production builders throughout the southwest region as it was expected that a successful program involving the CSTRR team could become a model for other builders throughout the US.

Market Development Philosophy

A key element in CSTRR's market strategy was based on the design and construction expertise of Pulte Homes, the largest US homebuilder and one of the largest homebuilders in the Las Vegas and Phoenix markets. In 1999 Pulte constructed over 1100 new homes in Las Vegas and expects that rate to continue into 2000. It was expected that Pulte Homes would also provide financing expertise through their Pulte Home Mortgage division that finances over 35% of their homes sold.

In marketing the product, Pulte was expected to team with Nevada Power in the development and implementation of a marketing program that would present the "right" message to the prospective buyer, generate the necessary, solar interested, traffic into the communities and sell the homeowner on the SWH appliance.

As the program progressed, CSTRR had the lead responsibility with the support of Pulte Homes and Nevada Power Company for the development and implementation of an effective outreach program that would engage other builders.

The marketing program was to include: 1) point-of-sale displays and brochures, 2) newspaper, radio and TV ads, 3) special events, and 4) Nevada Power promotions, and 5) innovative financing initiatives. As the project progressed, Pulte also planned ongoing market studies through exit interviews and focus group studies of prospective homebuyers and user surveys of SWH system purchases.

Market and Business Plan

With the aid of the CSTRR team, a Marketing and Business Plan was prepared in accordance with the Financial Assistance Statement of Work. This plan was submitted to the Department of Energy (DOE), Golden field Office for review and approval on February 1, 1999. The DOE approved this plan shortly thereafter. The approved plan is provided in Appendix K.

Task 4 – Pilot Program Implementation

Background

Under this task Pulte was expected to install 9 SWH systems into model homes, (6) systems in two Las Vegas subdivisions and (3) systems in a single Phoenix subdivision. In preparation for these installations, Pulte was expected to complete the design integration of the systems, prepare and execute installer and sales staff training programs, resolve any barrier issues, e.g., acquiring building permits for SWH.

Also under this task the CSTRR team was required to develop the marketing and sales program. The marketing program was to include: 1) point-of-sale displays and brochures, 2) newspaper, radio and TV ads, 3) special events, and 4) Nevada Power Company promotions. As the project progressed, Pulte also planned ongoing market studies through exit interviews and focus group studies of prospective homebuyers and user surveys of SWH system purchases.

Results of the Design and Installation Program

Contrary to original plans, Pulte did not prepare detailed design drawings for the installation, but rather planned the final installation of the collector through on-site inspections of the residence and the general guidance provided by Pulte with recommendations from the manufacturers for collector placement in relation to the water heater. Both manufacturers recommended that the collector be located in close proximity to the water heater, but not more than 100' away. This condition was easily satisfied. Pulte added an additional constraint that no collector shall be placed facing the street. Fortunately, this later restriction did not create any difficulties and all collectors were successfully located in an approximate southerly direction. Piping runs were also easily maintained at minimum distances. From these installation experiences it can be concluded that most Pulte homes could accommodate SWH systems without violating Pulte or manufacturer guidelines.

Installer training procedures was yet another deviation from original plans as Pulte relied entirely on the manufacturers for installer training without the aid of any training procedures. A single training session in each city was scheduled and manufacturer representative(s) actively participated in the training session. The Las Vegas session was the most comprehensive training session and was attended by Pulte site supervision and inspection, the roofing contractor, the plumbing contractor and the structural engineers. Both manufacturers presented their installation procedures without the benefit of written materials.

The permitting process was a non-event in both cities. In Nevada, the only requirement is that the installer is required to have a solar license. Since the plumbing contractor already had the necessary license, no problems were experienced. Building inspectors did not raise any issues with the design nor the installation. Very likely, the prominence of the Pulte name was instrumental in the ease in which this process proceeded. In Phoenix, Sun Systems, Inc. is a licensed solar installer and they too did not encounter any issues with the permitting and final inspection process.

Six ICS system installations were installed in Las Vegas (two more than originally planned as two sets of model homes were outfitted with SWH systems at the Stallion Mountain subdivision) without incident. The installation crews complemented the ICS design for its simplicity of installation. It

was estimated that the total time to install the complete system was less than 4 hours. Two issues with the ICS design were the added provisions needed to accommodate the weight of the filled system and the added logistical problems with lifting the collector onto the roof. As previously noted Pulte's structural engineers analyzed the roof loading of a filled collector and concluded that cross braces would be necessary between the roof trusses bearing the weight of the collector. Since the collector is installed prior to installing the sheet rock, this was not a problem and required a few minutes to complete.

Lifting the 200-pound dry collector onto the roof was performed by the roofing crew although that is not within their normal work scope. They were the only subcontractor with a front-end loader on site. This required coordination and delivery of the collector at the time the roof tile was being placed on the roof, which is the only time, the front-end loader is on-site. Although this would appear to be a trivial problem, it actually was cause for great concern, but was accomplished.

Three Heliodyne systems were installed (one more than originally planned with one at the Crown Ridge site and two at the Stallion Mountain site). These installations required at least 8 hours, over twice that of the ICS design, and all of the installations required corrective actions before they operated satisfactorily. From an aesthetic viewpoint none of the systems were satisfactory even after corrective changes were made to repair visual defects. Not surprisingly, the installers universally preferred the ICS for the simplicity of its design, its ease of installation and its final appearance.

The Heliodyne installation issues were as follows:

Collector/roof integration – As noted earlier, without a sheet metal pan to collect and distribute rainwater and possible leakage from the collector, Pulte required the installation of 90 pound felt under the collector and the placement of the collector near the eaves so that the felt could be extended to the bottom of the roof. This resulted in an unsightly installation, as the collector and felt were readily visible.

Collector plumbing – Insufficient care was taken when placing the collector and plumbing penetrations were not optimized with the collector outputs resulting in excessive and prohibitively unsightly plumbing runs on the roof. After the addition of the pipe insulation, this collector piping became even more unsightly. To further exacerbate the piping problem, the plumber covered the insulation with silver duct tape. Some attempts were made to correct the unsightliness by painting the duct tape, but none of the installations were very satisfactory.

Air vents – On two installations, the plumber neglected to add the air vent. When so advised the plumber retrofitted a gate valve rather than the intended air vent resulting in an unsightly appearance. The gate valves were later replaced with a conventional vent valve.

Pre-assembled plumbing assembly on the hot water tank – As with the Sun Systems design, Heliodyne has a pre-assembled plumbing assembly for installation onto conventional water heaters. However, this design has many more components and even though Heliodyne has a very professional assembly, once the piping and components of the pre-assembled unit are insulated, it begins to assume a very unsightly appearance. Many negative comments were made by Pulte staff regarding the complexity and general appearance in the mechanical room. Much of this issue would be resolved with the newer Heliodyne design using a PV

powered pump and thermosyphon heat exchanger. A suitable cover could also be used to improve the equipment appearance.

Sensor wire – Pulte plumbers refused to install the sensor wire since it is not the function of the plumber to perform electrical work. Pulte site managers resolved the problem by personally wiring the sensor. This problem would also be non-existent with the newer Heliodyne system.

Mixing valves – The mixing valve was not pre-packaged by Heliodyne causing several problems. First, on two installations, the plumber simply did not install the valves until it was brought to their attention. When they did install the mixing valve, they installed it incorrectly.

Air purging – Two of the systems were improperly purged and the system stagnated. After purging the air, the systems operated perfectly.

In summary, the Heliodyne complexity, general appearance and installation problems were a sufficient concern to Pulte managers that a decision was made to discontinue the use of the Heliodyne system from future consideration. The logistics of managing two designs was also instrumental in this decision.

It is noteworthy that throughout the installation process, problems encountered with the Heliodyne system installations were identified by CSTRR representatives or as the result of observations made by others. On-site Pulte inspection staff did not play an active role in overseeing the installation and startup as was expected. Perhaps, if a significant number of systems were installed or if the SWH were to be used as a standard option, Pulte inspectors would take a more active role.

Of interest, the installation of two, not three as planned, Sun Systems, Inc. collectors at the Phoenix site were a greater problem than in Las Vegas as Pulte/Phoenix personnel relied entirely on Sun Systems staff for the installations. Since Sun Systems personnel were not on-site, the logistics of coordinating with the construction crews resulted in excessive lost time for Sun Systems personnel.

Results of the Market Development Program

At the onset of this program, it was CSTRR's conviction that the CSTRR team and the market strategy and planning would provide the greatest opportunity for success in the penetration of SWH into the new residential market. Further, CSTRR expected that success as result of this project would evolve into a much broader program. The basis for this belief was the success elements in this project:

- CSTRR's builder partner, Pulte Homes and then the largest homebuilder in the US and the US leader in energy efficient construction.
- Other key partnership support – Nevada Power Company, Nevada's largest electric utility, the State Energy Office and University of Nevada solar experts
- Economic advantages of new construction – targeting new construction reduces both the installation and marketing expenses

- Las Vegas and Phoenix markets – two of the most dynamic new construction markets in the US
- Solar resource – both cities have more sunshine than any other major cities

Given this formula for success, the Marketing and Business Plan was prepared and included plans for:

- Development and implementation of a sales training program for the model home sales staff
- Development of point-of-sale displays and brochures for the model home sites
- Development and release of newspaper ads and radio/TV ads
- Special events, e.g., a “solar summit” and “grand opening” ceremonies
- Development and distribution of promotional materials by the Nevada Power Company
- Development and implementation of “lessons learned” exercises with prospective homebuyers who either purchased or rejected SWH. “Lessons learned” were to include exit interviews, focus group studies of prospective homebuyers and user surveys of SWH system purchasers.

As with the installer training, a formal training program was not used to train the sales staff. Rather, Pulte elected to hold a sales training program in Las Vegas lead by CSTRR and supported by the two SWH manufacturers prior to a grand opening ceremony for the Stallion Mountain subdivision. Approximately 15 members of Pulte’s sales/marketing department participated including the marketing VP.

In Phoenix the marketing VP was briefed on the project and an on-site sales training was held with the sales staff. Sun Systems, Inc. staff participated in the Phoenix sales training activities.

Promotional materials and point-of-sale literature prepared for the sales offices and for special events included:

- Press release materials
 - CSTRR solar energy brochure
 - Press release for use in conjunction with CSTRR’s “solar summit”
 - Advertising copy
 - Insert materials for CSTRR’s news letters
- Sales brochures and materials
 - Sun Systems, Inc. product brochure and a cutaway model
 - Heliodyne product literature and full-scale model

- Poster board displays for the model home display areas
- One-page flyers highlighting system economics and environmental benefits
- Related news articles for handout at the model homes

Pulte introduced a special financing initiative for the Las Vegas market, which was a 1/8-point interest rate discount for the SWH homebuyer who used Pulte's mortgage service. This discount was for the entire mortgage. For a \$200,000 mortgage this translates into a \$250 annual savings and was expected to be an extremely powerful tool in the sale of SWH systems. In Phoenix, Pulte did not provide this rate discount as Arizona has a 25% tax credit.

Nevada Power Company also committed to a \$75 rebate for those SWH systems connected to electric water heaters.

Task 5 – Pilot Program Evaluation

Background

In this the final phase of the program, the CSTRR team planned to evaluate the overall program success in meeting the projects goals and objectives:

- Success in meeting sales goals
- Product compliance with expectations for performance, economics, reliability/durability, and aesthetics
- Completeness and effectiveness of the training programs
- Overcoming any barriers in the design and installation of the product.
- Pulte Homes responses to the SWH initiative and continued interests in SWH as a residential option or standard appliance
- Successes in the adoption of SWH by other builder/developers
- Pulte Homes satisfaction with the product, its performance/economics, installation, aesthetics, reliability/durability
- Buyer interest and acceptance of the product
- Effectiveness of financing initiatives as a marketing tool
- Comparative performance of the indirect and ICS systems under simulated operating conditions

Pilot Program Evaluation Results

Product sales goals:

CSTRR and Pulte's expectations for this program were that a minimum of 20 SWH systems would be sold in Pulte's Las Vegas communities during 1999 with 10 more in the Phoenix market. Over the next five years, sales were expected to exceed 5000 units with annual production of 2000 units per year. In fact, no systems have been sold in either the Las Vegas or Phoenix markets as of May 2000 other than those installed on model homes. In May 2000, Pulte announced that they would no longer participate in this SWH program although they would continue to offer the product in their Las Vegas and Phoenix markets.

On several occasions, Pulte management considered adding the SWH package on the residences of a single subdivision as a standard appliance, but the marketing department rejected this, as the added cost would have affected the competitiveness of the housing product. It should be noted that the housing markets in Las Vegas are extremely competitive with many projects operating on less than 10 % margins. Thus the free SWH would represent a significant reduction in the homebuilder's profits.

The reason for this failure to meet the sales goal is that SWH simply doesn't compete with other more attractive home options. As Pulte's sales staff noted, SWH must compete with many buyer options, e.g., carpet upgrades, countertop upgrades, tile floors, fireplaces, and a host of other upgrades. A budget conscious buyer with limited borrowing power foregoes SWH in favor of the other options. Even the "solar advocate" and "green" consumer were not willing to make the sacrifice. Many potential buyers had heard of Pulte's solar option as a result of public relations announcements, advertising and news reports. Some expressed an interest until faced with the hard choices and in every instance SWH lost.

The systems and installations were not the issue except for an occasional opposition to the Heliodyne system, largely the result of poor installations as previously discussed. There were no apparent built-in biases from the horrors of the 70's and early 80's. The problem very simply is that there is no strikingly compelling reason to buy solar in a cheap and plentiful energy economy. The \$60 annual savings in Las Vegas is 4 pulls on a \$5 slot machine, just not enough to get neither the customer nor the sales personnel excited.

Product:

A great deal of effort was expended to identify the best product and best manufacturer of the product. Not surprisingly, at the start of the program, there was no general agreement within the CSTRR team on the "best" of either. The SRCC analysis commissioned by CSTRR, the site visits to the manufacturers and the follow-up studies to confirm the reliability/durability of the choices proved to be invaluable. It was extremely beneficial to have the Pulte Homes Director of Construction visit the factories, review manufacturing processes, assess quality controls, review the products and their construction, discuss installation procedures and visit installations in the vicinity of the factories.

It was equally important that supporting studies were conducted to resolve any lingering questions. The performance/economic analyses and other studies were needed to compare the tradeoffs between performance and economics, ease of installation and

reliability/durability. The assessment of the impacts of collector orientation and hot water load profiles on performance convinced the team that collector placement on east or west facing roofs would be acceptable and that hot water load profiles should be a consideration in the sale of ICS units.

Investigations of reliability and durability issues was also invaluable particularly the freeze question regarding the ICS design. This test confirmed the Sun Systems, Inc. design choice over the other two ICS designs for the Las Vegas market, as this design was the only one, which will survive temperature extremes. Examination of the maintenance issues with the indirect design contributed to the reassurance that these expenses are manageable. It also emphasized the importance of minimizing system components through the substitution of advanced designs.

Aesthetics was a non-issue with the ICS design. The installations on the roof and in the mechanical room were very acceptable to the installers, the marketing/sales staff, and consumers. Construction and sales staff Interviews confirmed general satisfaction with the installed appearance of the ICS systems. A number of comments were made that its general appearance is "like a skylight".

The appearance of the Heliodyne unit was an issue for some. The finished product on the roof and in the mechanical room were considered unacceptable to about half those interviewed. In interviews with the sales staff at the subdivisions, some showed no concern; others described the installed system as "ugly".

In the end, the performance advantages of the indirect design proved to be less important to Pulte than the ease of installation of the ICS design. However, having said that, the economics of neither system proved to be satisfactory. Energy savings with neither system provide the necessary return on investment at today's energy prices.

Installer Training:

The training program for the ICS system proved to be adequate as all the installations of the ICS systems generally proceeded without incident once the logistics of lifting the collector onto the roof was resolved. No problems were encountered with any of the six systems installed and subsequent inspections proved that all are performing satisfactorily.

As noted earlier, problems were encountered with all the Heliodyne installations confirmed the ineffectiveness of the installer training. Training procedures were not documented, checklists were not prepared and no records were maintained. On-site supervision and inspection was very limited. CSTRR or others identified most of the installation problems. Some of the errors were: incorrect or missing mixing valves, reversal of the input/output lines, failure to properly insulate pipes, failure to install the vent valve, failure to properly purge the system of air, failure to install the controller sensor. In the view of seasoned solar personnel involved in this project, these problems were not unlike similar problems which have plagued solar hot water systems since their inception.

Final inspections at the completion of the installations should have identified these problems, but were not identified by either the supervision or inspection. There appears to be a lack of commitment by the line personnel at these subdivisions and without this commitment it is not

likely that these problems can be avoided in the future. A more aggressive Pulte supervision and inspection is needed to prevent this problem in the future.

Sales Training:

Based on follow-up discussions with sales personnel after the sales training program, the sales training instruction was generally not effective in creating an effective sales initiative. The sales staff expressed little motivation to sell solar and generally didn't encourage the solar product over other options. One of the reasons given was that the sales staff work on commissions and a \$39 commission on a SWH sale is not sufficient motivation particularly since many customers are working within a budget limit. SWH is competing with other options having higher priorities, e.g., carpet upgrades, countertop upgrades, tile floors, fireplaces, window upgrades and if the customer doesn't buy SWH, they'll buy something else until their budget limit is reached. From a salesperson perspective it's a "zero sum" game. One of the more interested sales staff mentioned that higher SEER air conditioning saves more energy dollars at less cost than SWH and that doesn't sell either. Financial incentives for the sales staff were considered, but rejected, because it was felt that historically these incentives have not been effective.

The "green power" message was discussed in the Sun Systems, Inc. SWH brochure and additional point-of-sale handout materials were developed based on data generated by the Environmental Protection Agency (EPA). Even the buyers initially expressing an interest in SWH quickly lost interest when confronted with the installed system price and meager savings. Even the "green power" advocate was not motivated to make the economic sacrifice.

One of the arguments presented in the sales material was that the combined monthly mortgage and energy bill will show a saving when the benefits of the eighth point interest rate (Las Vegas) or 25% tax credit (Phoenix) are applied. This argument did not motivate either the sales staff or the homebuyer.

A number of sales meetings were held by the CSTRR team to identify the causes for the marketing problem and to formulate strategies to overcome the lack of interest. On-site sales staff was interviewed and Pulte's marketing consultants were consulted. It was these meetings that resulted in some of the point-of-sale materials and more were planned, but discontinued when Pulte declined to proceed. During these sales meetings, it was agreed that some additional sales training might help, but it is not expected to completely solve the problem, as sales training program is only a small part of the reason for Pulte's inability to generate sales. *Until the homebuyer of the future becomes more energy'and/or environmentally motivated, as occurred in the mid to late 70's, it is unlikely that SWH will become a prominent appliance in the home.*

Lack of Pulte marketing management support for the SWH project was noted. The need for this support cannot be over-emphasized. Commission-rewarded on-site sales personnel are not motivated to sell solar given the small commission percentages. Directives from their management are needed to assure a more aggressive on-site sales effort.

Barriers to the design and installation of the product.

In accordance with the Financial Agreement, all systems were required to be SRCC certified for the fuel of choice. The systems under consideration were not certified for gas, but this certification was quickly and easily granted by SRCC at the request of the manufacturers selected under this project.

Federal, state and local codes and standards were also easily satisfied. There was almost no evidence of any code or permitting barriers in either city. Nevada requires a state license for the solar installer. Pulte's plumbing contractor had this license and Pulte applied for and routinely received the permit.

In Phoenix, the city requires a system certification as well as an installer's license. Sun Systems, Inc. had previously received this certification and license.

Product Satisfaction:

Pulte management and installer and sales staff was very satisfied with the Sun Systems aesthetics. Insufficient time and experience was accumulated on the systems to reach definitive conclusions regarding the performance, reliability and durability. Information provided by CSTRR and University experts was generally accepted as proof that there was little to be concerned with in this regard. Similarly, based on discussions with sales staff, prospective SWH buyers were generally unconcerned with the aesthetics, performance, reliability or durability of the Sun Systems, Inc. system.

Reactions to the Heliodyne systems were not as favorable, but not universally bad either. As mentioned in earlier sections of this report, some installer and sales staff members and prospective buyers were critical of the "mess on the roof" and the "Rube Goldberg" assembly on the hot water tank. Others had almost a completely alternative viewpoint and considered the system "high tech". The collective reaction to the Heliodyne system strongly suggests that unless the far less complicated PV version is used, adequate sales will not result.

Financing:

This subject was one of the big disappointments of this program and resulted in one of the biggest non-solar surprises. Imagine! Pulte Mortgage offered an eighth point discount worth \$250 annually on a \$200,000 mortgage and it didn't sell. The reasons provided by the sales staff were that only 35% of the Pulte homebuyers use Pulte Mortgage. They also commented that many buyers pay cash or make very large down payments so that even those buyers using Pulte Mortgage are not able to benefit from the discount. It was also noted that the average buyer lives in a home for an average of five years and therefore is not able to realize the full benefit of the discount.

In Phoenix, the 25% tax credit translates into a \$600 one time saving and at the installed system price of \$2500 (\$100 more than Las Vegas) this reduces the price to \$1875. Since this was the target price for a system in Las Vegas when this project began, it suggests that the trigger price for consumer acceptance must be substantially less than Pulte's \$2400 price.

Outreach:

CSTRR prepared a draft Outreach Plan and conducted those activities which could be implemented during the early phases of the program. The remainder of the plan required the acceptance of the SWH product. Since this didn't occur, the outreach activities were discontinued.

As the project evolved, the Summerlin Corporation who expressed an interest in participating in the SWH project contacted CSTRR and the possible use of solar energy for other uses in this 30,000-acre master planned community. CSTRR was also contacted by two other residential builders in Las Vegas. In Phoenix, Pulte had advised that they expected to pursue the SWH option in other Phoenix and Tucson subdivisions. Clearly, a success with CSTRR's Pulte project could have created the successes envisioned for SWH as a direct result of this project. Those expectations have dimmed as a result of the negative sales experience and are a great disappointment to CSTRR and the other team members.

Product Performance:

In the course of this project, CSTRR's team members planned to conduct simulated in-service testing of the SWH products using systems installed on model homes. Later in the program these in-service test results were to be confirmed using production systems. These test plans were modified at the request of the DOE Golden Field Office. The modified test plan substituted a test program to be conducted by the University of Nevada, Las Vegas (UNLV) for the model home and production system tests. Based on this revised plan a Test Plan was prepared (see Attachment L). In this revised plan, two Sun Systems, Inc. systems and one Heliodyne system were installed in a test setup at UNLV. The second Sun Systems, Inc. system was to be used to validate system performance projections when operating with an above normal morning hot water load.

A complete description of the test setup is provided (see Attachment M). These tests are currently in progress. Incomplete results are available at this time and therefore no definitive conclusions can be made at this time. The UNLV researchers will report the results of these tests at a later date.

APPENDIX A

SWH SELECTION CRITERIA

PRODUCT

PERFORMANCE

SRCC qualifications - electric & gas and/or plans for SRCC qualification

Per cent load based on:

SRCC ratings

Typical user load profiles

System configuration, i.e., collector & storage size,

Roof mount

Roof orientation

Economics for each configuration w/local utility rates

AESTHETICS

General appearance of:

Roof mounted system for typical Pulte home design

Collector connections & other exposed collector hardware

Storage tanks, pumps, valves, and/or other ancillary equipment

Conformity of collector with roof matl's, structures

RELIABILITY/DURABILITY

Warranties

Lifetime of materials w/emphasis on:

Mounting hardware exposed to elements

Absorber material

Glazings

Storage tank liner materials

Auxiliary components - pumps, valves, controls, protective devices

Protection from extended stagnation conditions

Estimated reduction in lifetime

Impacts on material life, appearance degradation, performance

Retention of visual appearance after extended stagnation and/or operating life

Hot fill protection & availability of test data

Freeze protection @ worst case Las Vegas conditions

Component compatibility with local water conditions & availability of test data

Protection from collateral damage due to failure of any component

Hot water-tempering provisions

ECONOMICS

- Product cost w/all required hardware
- Estimated Installation expense based on local labor rates
- Simple payback based on installed retail cost
- Payback sensitivity to alternate lifestyle conditions

INSTALLATION

- Compliance with local codes & standards
- Degree of installation complexity & installer training requirements
- Estimated time to install
- Availability of manuals & training programs

PRODUCER CRITERIA

PRODUCTION

- Production capacity & large scale production capability
- Degree of automation
- Quality control systems
- Willingness to establish manufacturing facilities in Nevada

DESIGN SUPPORT

- Willingness to modify the design to meet builder requirements
- Quality of test & analysis programs

FINANCIAL STRENGTH

- Financial statement
- Cost share

DISTRIBUTION

- Availability of local distributor or willingness to establish a local distributor
- Distributor training & support program
- Distributor oversight/quality control program

APPENDIX B

SRCC CERTIFICATION CRITERIA^{**}

Table 1 Features Evaluated During the SDHW System Design Review

Operating Limits Solar Loop Isolation Thermal Expansion Auxiliary Water Heating Equipment Back Thermosyphon Prevention Fluid System Sizing	Vacuum Induced Pressure Protection Thermal Shock Protection Different Metallic Materials Airborne Pollutants Effects of Decomposition Products	Manual Control Override Wiring Identification Temperature Control Code Compliance
Collector UV Radiation Protection Collector Flow Distribution Collector Circulation Control	Storage Tank Tank Insulation Expansion Tanks Heat Exchanger	Insulation Piping Filters Joints Materials

Table 2 Features Evaluated for Durability and Reliability Criteria

Stagnation Solar Degradation Operation Conditions Incompatible Materials Freeze Protection Protection From Leaks Fluid Compatibility	Deterioration of Fluids Thermal Storage System Buried Components Deterioration Protection Water Hammer Sound and Vibration Control
--	---

Table 3 Features Evaluated for Safety Criteria

Protection of Electrical Components System Failure Prevention High Temperature Control Protection Against Auto-Ignition of Combustibles Fluid Safety Labeling Contamination of Potable Water Entrapped Air	Backflow Toxicity Combustible Liquids Liquid Flash Point Pressure Relief Heated Components
--	---

Table 4 Features Evaluated for Operation and Service Criteria

Operating Indicators Tanks Waste Disposal	Dirt Retention and Staining Maintenance and Servicing Permanent Maintenance Accessories
---	---

Table 5 Features Evaluated for Installation Criteria

Firestopping Auxiliary System Space Use Accessibility Building Penetrations Water Damage Structural Supports Expansion and Contraction of Supports Penetration of Structural Members	Protection from Thermal Deterioration Tilt and Azimuth Shading of Collector Pipe and Component Supports Pitch or Angle of Piping Installation Underground Piping Control Sensor Installation Penetrations Through Fire-Rated Assemblies Emergency Egress and Access
--	---

Table 6 Features Evaluated for O & M Manuals

Provision for Manuals Installation Instructions Operation Instructions Maintenance Plan	Fluid Quality Service and Replacement Parts Hazards Warranty Coverage
--	--

^{**} Directory of SRCC Certified Solar Collector and Water Heating System Ratings, SRCC Manual, July, 1998

APPENDIX C

ASSESSMENTS – MANUFACTURERS

PERFORMANCE – GENERAL

Highest rating:	Indirect & drainback designs
Load sensitivity:	ICS is most sensitive Indirect & drainback are least sensitive
Temp. Sensitivity:	ICS is most sensitive
Concerns:	Possible influences on ICS performance due to effective aperture Basis for low rating of drainback designs
All systems:	Possible performance gain w/black chrome

SRCC RATINGS

ELECTRIC AUX.

Manufacturer	Type	Model No.	Rating SEF	Savings kW-hr	Coll. Area Sq. ft.	Storage Gal.
Heliodyne	Indirect	DWCL HP 408 G 65	1.7	2600	32.3	65
Radco	Drainback	DBHX-8-D-40P	1.4	2000	39.9	65
Sun Systems	ICS	4850	1.4	1800	36.1	39
Sun Earth	ICS	CP-40	1.4	1900	24.9	42
Sun Earth	Draindown	TE32C-80-2	1.5	2200	32.8	80
TCT	ICS	PT-40-CN	1.6	2300	32.1	40

GAS AUX.

Manufacturer	Type	Model No.	Rating SEF	Savings Therms	Coll. Area Sq. ft.	Storage gal.
Heliodyne	Indirect	DWCL HP 408 G 65	0.9	100	32.3	65
Heliodyne	Indirect	DWCL HP 408 G 80	1.1	120	48.1	80
Radco	Drainback	DBHX-8-65-GD-40P	0.9	100	39.9	65
Radco	Drainback	DBHX-8-80-GD-64P	1.1	125	64.6	80

PERFORMANCE/RELIABILITY/DURABILITY COMPARISONS

General:

Pluses: Aesthetics not an issue with any of the designs
All systems well designed, w/good materials selection, sturdy construction
Materials & designs to prevent outgassing & fogging
QC controls very good, all collectors pressure tested

Comparisons:

Indirect concept: Best performance
Mandatory fluid maintenance req'd
Overtemp protection req'd to limit tank temp

ICS Easiest to install
Lowest maintenance cost
Sensitive to load profile

Drainback Most sensitive to installation error
Performance listed in SRCC rating is questioned

Concerns: ICS - Freeze potential of ICS design
Possible stagnation problem if not used
Potential for pitting corrosion

Indirect Periodic changeout of anti-freeze req's
Filling & bleeding

Drainback Plumbing & installation

Economics: Must be analyzed based on load profile w/scheduled & unscheduled maintenance

MANUFACTURER COMMENTS

Heliodyne - Indirect:

- Pluses:** Should have highest performance
Well designed
Excellent pre-packaged plumbing
Local water not a problem
- Concerns:** Anti-freeze requires periodic replacement
Replacement cost of pumps & controls

Radco - Drainback:

- Pluses:** Best drainback tank design
Local water not a problem
- Concerns:** Drainback requires careful installation of plumbing

Sun Earth - Drainback:

- Pluses:** Drainback tank design adequate
Local water not a problem
- Concerns:** Drainback requires careful installation of plumbing

Sun Systems - ICS:

- Pluses:** As with all ICS, simplicity of installation & maintenance
.058" absorber tubes should increase tolerance to pitting corrosion from poor water
Pre-fab plumbing package
- Concerns:** Freeze potential - 20 °F rating
Performance sensitivity to load profile & ambient temp.
Accuracy of SRCC rating
Reduced efficiency due to ineffective absorber area, single glazing, & black paint

Sun Earth - ICS

- Pluses:** As with all ICS, simplicity of installation & maintenance
Absorber nearly matches aperture
.058" absorber tubes should increase tolerance to pitting corrosion from poor water
- Concerns:** Freeze potential - 20 °F rating
Performance sensitivity to load profile & ambient temp.
Lack of pre-fab plumbing package

TCT - ICS

- Pluses:** As with all ICS, simplicity of installation & maintenance
Best match of absorber to aperture
Best ICS performance rating, dbl glazing helps & black chrome would add further
Best ICS low temp rating - 10 °F
Simple pre-fab plumbing package
- Concerns:** .040" absorber - least tolerant ICS to pitting corrosion
Effectiveness of absorber foil between tubes
Number of welds & potential for leaks
Performance sensitivity to load profile & ambient temp.

INSTALLATION

General:

- Ranking:** Best - ICS, easiest & least sensitive to installation error
More difficult - Indirect, pre-fab plumbing package helps, req's trained plumber
More difficult - Drainback, requires trained plumber, supervision and inspection
- Other issues:** Collector wt. - ICS requires hoisting eqmt
Indirect & drainback collector wt. not a problem
- Scald protection - Most important w/Indirect & drainback
Some protection required w/ICS

MAINTENANCE

- Ranking:** Best ICS, lowest maintenance barring local water problem
Acceptable Drainback, provided properly installed,
Pumps & controllers are low maintenance, but can fail
Acceptable Indirect, provided properly installed
Anti-freeze must be changed as req'd
Pumps & controllers issue similar to drainback

APPENDIX D

ANNUAL PERFORMANCE OF OG-300 CERTIFIED SYSTEMS IN LAS VEGAS, NEVADA

September 1998

Solar Rating and Certification Corporation
c/o FSEC, 1679 Clearlake Road
Cocoa, FL 32922-5703
(407) 638-1537 (407) 638-1010 Fax

SOLAR RATING AND CERTIFICATION CORPORATION

Estimated Annual Performance of OG-300 Certified Solar Water Heating Systems in Las Vegas, Nevada

Introduction

The Solar Rating and Certification Corporation (SRCC) is a non-profit organization whose primary purpose is the development and implementation of certification programs and national rating standards for solar energy equipment. The SRCC was incorporated in October of 1980 as an independent third-party certification entity. It is governed by a twelve-member board of Directors with representation from the public, private and generalist Sectors. It is unique in that it is the only national certification program established solely for solar energy products. It is also the only national certification organization whose programs are the direct result of combined efforts of state organizations involved in the administration of standards and an industry association.

The combined programs of the Solar Rating and Certification Corporation provide one-time certification, national recognition, product credibility, and standardized comparisons of solar energy products. The SRCC programs serve three primary constituencies: the solar energy industry, solar consumers, and state and federal regulatory bodies. All three constituencies benefit from the SRCC programs by obtaining a national state-of-the-art rating system, a mechanism to develop consumer confidence, and a rational and defensible criterion for tax credit qualification and other solar incentive programs.

The OG-300 certification program for solar water heating systems was established in 1992. It integrates results of collector tests and system tests with evaluations against minimum standards of system durability, reliability, safety and operation; as well as factors affecting total system design, installation, maintenance and service. A copy of the certification requirements¹ is available from SRCC.

Performance Estimation Procedures

SRCC uses a computer model² to estimate the thermal performance of solar water heating systems under specified conditions. A separate computer model for each system is developed from test data on some of the system components, manufacturer's literature on the others, and theoretical calculations. The SRCC rating calculated using the computer model is called the Solar Energy Factor. It is published in a Directory and in a summary booklet³. These ratings are based on conditions similar to the ones defined by the U.S. Department of Energy for testing conventional water heaters. These conditions describe

¹ "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems", April 1997.

² "TRNSYS A Transient Simulation Program", Solar Energy Laboratory, University of Wisconsin - Madison, July 1994.

³ "Directory of SRCC Certified Solar Collector and Water Heating System Ratings" and the Summary are available from SRCC.

hot water usage for a single day. Keep in mind that these ratings are only estimates based on an assumed set of operating conditions and that your actual performance will vary depending your hot water usage pattern and actual weather conditions.

The estimated annual performance indicators given in the attached tables are different from the SRCC ratings and are not directly comparable. The annual performance listed in this booklet was developed to provide an estimate of how solar water heaters could perform over a whole year in a specific location. The SRCC rating estimates the performance of the systems under "rating" conditions. Once again, keep in mind that these ratings are only estimates.

Operating Conditions

The estimated annual performance listed in the attached tables is based on the following conditions:

Condition	Value
Hot water load	64.3 gallons (243 liters) per day drawn throughout the day with the maximum loads occurring at 8 am and 8 pm ⁴ .
Water mains temperature	Varied monthly using Las Vegas, NV values ⁵ .
Collector orientation	Facing south at a tilt of 19°.
Distance from collector to tank	25 feet (7.6 meters) pipe length (each way), 16 feet (4.9 meters) vertical rise.
Backup heater set point	125°F (51.7°C) ⁶
Weather conditions	TMY2 data for Las Vegas, NV ⁷
Air temperature around indoor tanks	$T_{air} + [(72 - T_{air})/3]$, this estimates the temperature in a garage.

For reference, a conventional 50 gallon electric water heater with an energy factor of 0.9 would consume 3,800 kilowatt hours (kWh) per year under these conditions and a 50 gallon gas water heater with an energy factor of 0.6 would consume 190 therms (including delivered energy and losses).

Table Entries

The tables give the estimated annual performance for all OG-300 certified solar water heating systems. There are separate tables for systems using electric and gas backup

⁴ This profile adapted from the 1995 ASHRAE Applications Handbook, Chapter 45, and "A Domestic Hot Water Use Database", Becker and Stogsdill, ASHRAE Journal, September 1990.

⁵ "F-Chart", Klein and Beckman, F-Chart Software, 1993.

⁶ This set point was chosen as a compromise between the Department of Energy recommendation of 125°F (51.7°C), the plumbing code 120°F (48.9°C) maximum allowable in showers and tubs, and the 135°F (57.2°C) used in the Department of Energy test for conventional water heaters.

⁷ "TMY2s, Typical Meteorological Years", National Renewable Energy Laboratory, June 1995.

water heaters. The systems are listed by company name, system name and model number. The remaining columns are as follows:

System Number: SRCC's reference number. This number is used to cross-reference a specific system in the Directory.

FTL: This is the Freeze Tolerance Limit. The Freeze Tolerance Limit is the temperature below which the solar water heating system might suffer damage due to freezing. This means that if the outdoor air temperature drops near the freeze tolerance limit it is necessary to follow the instructions in the owner's manual for protecting the system.

Energy Savings: This is the estimated annual performance of the system. This value is the quantity of energy that did not have to be provided by electricity or gas because of the contribution of the solar water heating system. Note that the electricity required to operate any pumps and controllers used in a particular system has been accounted for.

Comments: This column lists additional information regarding specific systems.

Solar Rating and Certification Corporation
Estimated Annual Performance of OG-300 Certified Solar Water Heating Systems
Las Vegas, Nevada
with Electric Backup

System Name	System Model	System Number	FTL (°F)	Energy Savings* (kWhr)	Comments
Heliodyne, Inc.					
Heliopak	16 DWCL HP 1 308 G 65 ACD	92013E	-60	1800	
Heliopak	16 DWCL HP 1 408 G 65 ACD	92013F	-60	2300	
Heliopak	16 DWCL HP 1 408 G 65 ACS	92010A	-60	2500	
Heliopak	16 DWCL HP 1 408 G 65 PVD	96004C	-60	2600	
Heliopak	16 DWCL HP 1 408 G 65 PVS	96003C	-60	2800	
Heliopak	16 DWCL HP 1 410 G 65 ACD	92013A	-60	2600	
Heliopak	16 DWCL HP 1 410 G 80 ACS	92010B	-60	2700	
Heliopak	16 DWCL HP 1 410 G 80 PVD	96004A	-60	2900	
Heliopak	16 DWCL HP 1 410 G 80 PVS	96003A	-60	3000	
Heliopak	16 DWCL HP 2 308 G 80 PVD	96004B	-60	3000	
Heliopak	16 DWCL HP 2 308 G 80 PVS	96003B	-60	3200	
Heliopak	16 DWCL HP 2 408 G 120 ACD	92013C	-60	3100	
Heliopak	16 DWCL HP 2 408 G 120 ACS	92010C	-60	3200	
Heliopak	16 DWCL HP 2 408 G 80 ACD	92013B	-60	3000	
Heliopak	16 DWCL HP 2 410 G 120 ACD	92013D	-60	3200	
Heliopak	DWCL HE HP 1 308 G 80 ACS	92010H	-60	2100	
Heliopak	DWCL HE HP 1 408 G 80 ACS	92010D	-60	2500	
Heliopak	DWCL HE HP 1 410 G 80 ACS	92010E	-60	2800	

Heliotrope General, Inc.					
Solar Sidebar	SS-100-24-H	95003C	-60	2500	
Solar Sidebar	SS-100-24-R	95003A	-60	2200	
Solar Sidebar	SS-100-32-A	95003B	-60	2600	
Solar Sidebar	SS-100-32-H	95003D	-60	2900	
Solar Sidebar	SS-100-32-R	95003E	-60	2600	
Solar Sidebar	SS-100-32-RC	95003F	-60	3000	

* A conventional 50 gallon electric water heater would consume 3800 kWh under these rating conditions.

Prepared for Las Vegas, Nevada by:
SOLAR RATING & CERTIFICATION CORPORATION
c/o FSEC • 1679 Clearlake Road • Cocoa, FL 32922 • (407) 638-1537 • Fax (407) 638-1010

Thursday, September 17, 1998

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System Name	System Model	System Number	FTL (°F)	Energy Savings* (kWhr)	Comments
Solar Sidebar	SS-200-40-80-A	97002B	-60	2800	
Solar Sidebar	SS-200-40-80-H	97002C	-60	3100	
Solar Sidebar	SS-200-40-80-R	97002A	-60	2900	
Solar Sidebar	SS-200-40-80-RC	97002H	-60	3200	
Solar Sidebar	SS-200-64-80-A	97002E	-60	3200	
Solar Sidebar	SS-200-64-80-H	97002F	-60	3500	
Solar Sidebar	SS-200-64-80-R	97002D	-60	3300	
Solar Sidebar	SS-200-64-80-RC	97002G	-60	3600	

Morley Manufacturing

High Sierra Drainback	HS60B/40	92014A	-60	2400	
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Nippon Electric Glass America, Inc.

Sunfamily	PK-20	92004B	21	2600	
Sunfamily	PK-20-PSS	92017E	21	2600	

Radco Products, Inc.

Copper Sunsation	CSHX100	94006C	17	2500	
Copper Sunsation	CSHX40	94006D	17	1600	
Copper Sunsation	CSHX60	94006A	17	2100	
Copper Sunsation	CSHX80	94006B	17	2400	
Drainback Heat Exchanger	R-DBHX-12-120-D-80P	92007I	-60	2800	
Drainback Heat Exchanger	R-DBHX-8-120S-80P	94007C	-60	2900	
Drainback Heat Exchanger	R-DBHX-8-65-D-40P	92007A	-60	2000	
Drainback Heat Exchanger	R-DBHX-8-65S-40P	94007A	-60	2200	
Drainback Heat Exchanger	R-DBHX-8-80-D-64P	92007C	-60	2500	
Drainback Heat Exchanger	R-DBHX-8-80S-64P	94007B	-60	2700	

Solahart America

SOLAHART	181K	92006C	-21	1900	
SOLAHART	181K-AS	92009C	-21	1900	
SOLAHART	302J	92006B	-21	2300	
SOLAHART	302J-AS	92009B	-21	2300	

* A conventional 50 gallon electric water heater would consume 3800 kWh under these rating conditions.

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System Name	System Model	System Number	FTL (°F)	Energy Savings* (kWhr)	Comments
SOLAHART	302K	92006A	-21	2700	
SOLAHART	302K-AS	92009A	-21	2500	

Sun Systems, Inc.

CopperSun	4850	97001A	20	1800	
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Sun, Wind and Fire

Sun-Pak	SP32CHE	94005E	-60	1800	
Sun-Pak	SP32CHE-I	94004E	-60	2000	
Sun-Pak	SP32PHE	94005A	-60	1700	
Sun-Pak	SP32PHE-I	94004A	-60	2000	
Sun-Pak	SP40CHE	94005G	-60	2100	
Sun-Pak	SP40CHE-I	94004G	-60	2300	
Sun-Pak	SP40PHE	94005C	-60	2100	
Sun-Pak	SP40PHE-I	94004C	-60	2300	
Sun-Pak	SP64CHE	94005F	-60	2700	
Sun-Pak	SP64CHE-I	94004F	-60	2800	
Sun-Pak	SP64PHE	94005B	-60	2600	
Sun-Pak	SP64PHE-I	94004B	-60	2800	
Sun-Pak	SP80CHE	94005H	-60	2900	
Sun-Pak	SP80CHE-I	94004H	-60	3000	
Sun-Pak	SP80PHE	94005D	-60	2800	
Sun-Pak	SP80PHE-I	94004D	-60	2900	

SunEarth, Inc.

CopperHeart	CC-30	92011A	20	1700	
CopperHeart	CC-40	92011B	20	2000	
CopperHeart	CC-60P	92011C	20	2400	
CopperHeart	CC-60S	92011D	20	2300	
CopperHeart	CP-30	92011E	20	1700	
CopperHeart	CP-40	92011F	20	1900	
CopperHeart	CP-60P	92011G	20	2300	

* A conventional 50 gallon electric water heater would consume 3800 kWh under these rating conditions.

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System Name	System Model	System Number	FTL (°F)	Energy Savings* (kWhr)	Comments
CopperHeart	CP-60S	92011H	20	2300	
SOLARAY	TE32C-80-1	93001B	-28	2400	
SOLARAY	TE32C-80-2	96001B	-28	2200	
SOLARAY	TE32P-80-1	93001A	-28	2300	
SOLARAY	TE32P-80-2	96001A	-28	2100	
SOLARAY	TE40C-80-1	93001D	-28	2700	
SOLARAY	TE40C-80-2	96001D	-28	2500	
SOLARAY	TE40P-80-1	93001C	-28	2600	
SOLARAY	TE40P-80-2	96001C	-28	2400	
SOLARAY	TE64C-80-1	93001H	-28	3200	
SOLARAY	TE64C-80-2	96001F	-28	3000	
SOLARAY	TE64P-80-1	93001G	-28	3100	
SOLARAY	TE64P-80-2	96001E	-28	3000	
SunSaver	NF40P-80S	95010M	41	2900	
SunSaver	NF40P-80T	95009M	41	2900	
SunSource	HX40P-80	95001E	-28	2300	
SunSource	HX64P-120	95001K	-28	2800	

Thermal Conversion Technology

ProgressivTube Passive Solar Wa	PT-30-CN	95002A	10	1900	
ProgressivTube Passive Solar Wa	PT-35-CN	95002B	10	1900	
ProgressivTube Passive Solar Wa	PT-40-CN	95002C	10	2300	
ProgressivTube Passive Solar Wa	PT-50-CN	95002D	10	2300	

Thermo Dynamics, Ltd.

Thermo Dynamics Solar Boiler	SB32-9 Paint PV	92018E	-60	2500	
Thermo Dynamics Solar Boiler	SB64-9 Paint PV	92018D	-60	3200	

* A conventional 50 gallon electric water heater would consume 3800 kWh under these rating conditions.

Prepared for Las Vegas, Nevada by:
SOLAR RATING & CERTIFICATION CORPORATION
 c/o FSEC ♦ 1679 Clearlake Road ♦ Cocoa, FL 32922 ♦ (407) 638-1537 ♦ Fax (407) 638-1010

Thursday, September 17, 1998

Page 4 of 4

Solar Rating and Certification Corporation
Estimated Annual Performance of OG-300 Certified Solar Water Heating Systems
Las Vegas, Nevada
with Gas Backup

System Name	System Model	System Number	FTL (°F)	Energy Savings* (Therms)	Comments
Heliodyne, Inc.					
Heliopak	16 DWCL HP 1 308 G 65 ACD Z	98001E	-60	85	
Heliopak	16 DWCL HP 1 408 G 65 ACD Z	98001F	-60	100	
Heliopak	16 DWCL HP 1 408 G 65 PVD Z	98002C	-60	110	
Heliopak	16 DWCL HP 1 410 G 65 ACD Z	98001A	-60	110	
Heliopak	16 DWCL HP 1 410 G 80 PVD Z	98002A	-60	120	
Heliopak	16 DWCL HP 2 308 G 80 PVD Z	98002B	-60	125	
Heliopak	16 DWCL HP 2 408 G 120 ACD Z	98001C	-60	125	
Heliopak	16 DWCL HP 2 408 G 80 ACD Z	98001B	-60	120	
Heliopak	16 DWCL HP 2 410 G 120 ACD Z	98001D	-60	125	
Heliotrope General, Inc.					
Solar Sidebar	SSG-200-40-50-A	98003B	-60	125	
Solar Sidebar	SSG-200-40-50-H	98003C	-60	145	
Solar Sidebar	SSG-200-40-50-R	98003A	-60	130	
Solar Sidebar	SSG-200-40-50-RC	98003H	-60	150	
Solar Sidebar	SSG-200-48-50-RC	98003I	-60	155	
Solar Sidebar	SSG-200-64-120-H	98003L	-60	170	
Solar Sidebar	SSG-200-64-120-RC	98003M	-60	175	
Solar Sidebar	SSG-200-64-120-RC-100	98003O	-60	160	
Solar Sidebar	SSG-200-64-50-A	98003E	-60	150	
Solar Sidebar	SSG-200-64-50-H	98003F	-60	165	
Solar Sidebar	SSG-200-64-50-R	98003D	-60	150	
Solar Sidebar	SSG-200-64-50-RC	98003G	-60	170	
Solar Sidebar	SSG-200-64-80-H	98003J	-60	170	
Solar Sidebar	SSG-200-64-80-RC	98003K	-60	175	
Solar Sidebar	SSG-200-64-80-RC-75	98003N	-60	160	

* A conventional 50 gallon gas water heater would consume 190 therms under these rating conditions.

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SOLAR RATING & CERTIFICATION CORPORATION
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System Name	System Model	System Number	FTL (°F)	Energy Savings* (Therms)	Comments
Radco Products, Inc.					
Copper Sunsation	CSHX100GB	98005C	17	115	
Copper Sunsation	CSHX40GB	98005D	17	75	
Copper Sunsation	CSHX60GB	98005A	17	95	
Copper Sunsation	CSHX80GB	98005B	17	110	
Drainback Heat Exchanger	R-DBHX-12-120-GD-80P	98004C	-60	140	
Drainback Heat Exchanger	R-DBHX-8-65-GD-40P	98004A	-60	100	
Drainback Heat Exchanger	R-DBHX-8-80-GD-64P	98004B	-60	125	

Thermal Conversion Technology

ProgressivTube Passive Solar Wa	PT-30-CN-G	98006A	10	85	
ProgressivTube Passive Solar Wa	PT-35-CN-G	98006B	10	85	
ProgressivTube Passive Solar Wa	PT-40-CN-G	98006C	10	100	
ProgressivTube Passive Solar Wa	PT-40-CN-GX	98006E	10	105	
ProgressivTube Passive Solar Wa	PT-50-CN-G	98006D	10	105	
ProgressivTube Passive Solar Wa	PT-50-CN-GX	98006F	10	105	

* A conventional 50 gallon gas water heater would consume 190 therms under these rating conditions.

Prepared for Las Vegas, Nevada by:
SOLAR RATING & CERTIFICATION CORPORATION
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APPENDIX E

SWH PERFORMANCE ANALYSIS for the LAS VEGAS & PHOENIX MARKETS

ANALYSIS OBJECTIVES:

To predict SWH system performance and economics under the operating conditions encountered in the Las Vegas and Phoenix markets for various SWH system designs configurations when used in the typical Pulte Home residence with appropriate consideration for: 1) home owner hot water use profiles, 2) typical financing alternatives; 3) local energy economics, and 4) future economic conditions.

SYSTEM DESIGNS

Two SWH system configurations are being considered in the Las Vegas market, the indirect forced circulation model and the integral collector storage model (ICS). Only the ICS system configuration is being considered for the Phoenix market.

The supplier of choice for the indirect forced circulation system is Heliodyne, Inc. using their model #SWCL HP 408 G 65. This model as listed in the SRCC manual uses the Heliodyne Gobi 408 collector, which has a 32.3. Sq. ft. collector area and is single glazed using low iron glass. The absorber material in this collector is copper with a black chrome absorber coating. For this application the conventional hot water tank will serve a dual function, i.e., as the solar storage tank and as the auxiliary water heater.

Three manufacturers are being considered as suppliers for the ICS systems, including Thermal Conversions Technologies (TCT), Sun Systems, Inc., and SunEarth, Inc. The models selected for consideration include:

TCT – Model #PT-40-CN with a 32.1 sq. ft. single glazed collector, selective paint absorber, 40 gal storage

Sun Systems – Model #4850 with a 36.1 sq. ft. single glazed collector, selective paint absorber, 39 gal. storage

SunEarth – Model #CP-40 with a 24.9 sq. ft. single glazed collector, selective paint absorber, 42 gal. storage.

ANALYTICAL CONCEPTS

The first step in the analysis program requires the calculation of system performance using the OG300 analysis methodology. This methodology takes into consideration:

- Solar insolation,
- Outdoor weather conditions,
- Local water supply temperatures,
- Hot water tank set point,
- Ambient temperatures at the hot water tank,
- Heat losses in the plumbing lines from the collector to the tank
- Parasitic losses incurred due to pumps, controllers, etc.
- Energy heat losses in the auxiliary hot water heater
- Typical hot water use profiles,
- Collector tilt & orientation

Most of the above parameters are either readily available from existing databases or reasonable assumptions can be made based on experience. The greatest uncertainty in system performance is expected to be caused by the hot water use profile. This use profile is especially important for the ICS configuration due to the potential for large heat losses during nighttime hours. The collector orientation will also influence system performance, but performance impacts due to orientation can be predicted with good accuracy provided the collector tilt angle and southern exposure is known.

Based on a predetermined set of operational parameters this methodology will provide expected values for:

- Annual energy delivered to the hot water load
- Annual energy supplied by the auxiliary energy system
- Annual parasitic energy required to operate solar components
- Annual energy cost w/o solar system

After computing the above energy parameters, the second phase of the analysis program will compute the economics of the solar system using two different financing methods; a cash purchase of the solar system and a solar system which is financed as part of the 30 year mortgage. In performing the economic analysis, local factors and factors used in the California Energy Commission analysis will be adopted. This analysis will take into consideration the following parameters:

- System installed cost
- Estimated maintenance cost
- Down payment, if any, and the amount to be financed
- Period of the loan to finance the system

- Interest rate
- Buyer tax bracket
- Annual energy cost w/o solar system
- Annual solar energy supplied (provided under phase 1 of this analysis)
- Annual auxiliary & parasitic energy used
- Fuel cost & annual fuel cost escalations
- System maintenance cost

Using the above parameters and the previously calculated system performance, this economic analysis will be used to compute net cash flow for both the cash purchase and home mortgage options. When the system is purchased using a 30-year mortgage, the net cash flow for the combined mortgage payment and energy payment will be calculated. For the cash purchase case, a simple payback schedule will be calculated.

ANALYSIS CASES

Seven analysis cases are planned to evaluate and compare the cost benefits of the SWH designs under consideration. These seven cases will evaluate the two locations, Las Vegas and Phoenix, two system design configurations, the indirect and ICS designs, and four models, the Heliodyne indirect system and three ICS systems. Three user load profiles will be analyzed including the SRCC profile, a morning load and an evening load. The seven case studies are as follows:

	<u>SYSTEM</u>	<u>LOCATION</u>	<u>USER LOAD</u>
Case 1	Indirect collector system	Las Vegas	SRCC profile
Case 2	ICS - TCT System	Las Vegas	SRCC profile
Case 2A	ICS - TCT System	Las Vegas	Morning load profile
Case 2B	ICS - TCT System	Las Vegas	Evening load profile
Case 3	ICS - Sun Systems System	Las Vegas	SRCC profile
Case 3A	ICS - Sun Systems System	Las Vegas	Morning load profile
Case 3B	ICS - Sun Systems System	Las Vegas	Evening load profile
Case 4	ICS - SunEarth System	Las Vegas	SRCC profile
Case 4A	ICS - SunEarth System	Las Vegas	Morning load profile
Case 4B	ICS - Sun Earth System	Las Vegas	Evening load profile
Case 5	ICS - TCT System	Phoenix	SRCC profile
Case 5A	ICS - TCT System	Phoenix	Morning load profile
Case 5B	ICS - TCT System	Phoenix	Evening load profile
Case 6	ICS - Sun Systems System	Phoenix	SRCC profile
Case 6A	ICS - Sun Systems System	Phoenix	Morning load profile
Case 6B	ICS - Sun Systems System	Phoenix	Evening load profile
Case 7	ICS - SunEarth System	Phoenix	SRCC profile
Case 7A	ICS - SunEarth System	Phoenix	Morning load profile
Case 7B	ICS - Sun Earth System	Phoenix	Evening load profile

ANALYSIS PARAMETERS

Parameters for conducting the performance and economic analysis are provided below. Where appropriate, the basis for the selection of these parameters is noted. These parameters were assembled from the best available sources. The system lifetime is assumed to be not less than 30 years.

PHASE 1 PARAMETERS - PERFORMANCE ANALYSIS

<u>PARAMETER</u>	<u>UNITS</u>	<u>BASIS FOR SELECTION</u>
Solar insolation & outdoor weather	TMY database	TRNSYS
Water main temp	Las Vegas 67 °F - summer 64.5 °F - winter Phoenix	F Chart F Chart
Hot water draw	64.3 gal. /day	SRCC procedure
Hot water tank set point	120 °F	Set point used by local builders
Ambient temp@ HW tank	Ave. outdoor Temp.	Assumes HW tank located in garage
Plumb'g heat losses	SRCC values	SRCC procedure
Parasitic losses	SRCC values	SRCC procedure
Aux. energy eff.	89% - electric 55-62% - gas (Tank size dependent)	SRCC procedure SRCC procedure
Hot water use profiles:		
Indirect system	SRCC draw profile	SRCC procedure
ICS		
Balanced draw	SRCC draw profile	SRCC procedure
Morning draw	See Attachment	
Evening draw	See Attachment	
Roof angle	5/12 pitch	Typical roof angle
Collector orientation	0, 30, 60, 90 Deg. From south	

PHASE 2 PARAMETERS - ECONOMIC ANALYSIS

PARAMETER	UNITS	BASIS FOR SELECTION
System installed cost		
Heliodyne	\$2000	Pulte Homes pricing
TCT	\$2000	Pulte Homes pricing
Sun Systems	\$2000	Pulte Homes pricing
SunEarth	\$2000	Pulte Homes pricing
Maintenance cost (EST.)		
Heliodyne	\$240 @ 7 th yr.	Replacement cost of Anti-freeze & pump
TCT	\$100 @ 10 th yr.	Misc. defects
Sun Systems	\$100 @ 10 th yr.	Misc. defects
SunEarth	\$100 @ 10 th yr.	Misc. defects
Down payment		
Cash purchase	100% of installed cost	
Incl. in mortgage	10% of installed cost - Ave. down payment	
Period of the loan		
Cash purchase	0 yrs.	
30 yr. Mortgage	30 yrs.	
Interest rate	6.5%	Current rate less 1/8%
Buyer tax bracket	Las Vegas Fed. - 28% NV - 0% Phoenix Fed - 28% State - 8%	
Fuel cost (Taxes incl.)		
Las Vegas		
Electric	\$0.0647/kW-hr	
Gas	\$ 6.26/mmbtu	
Phoenix		
Electric	\$0.092 (summer) \$0.0796 (winter)	
Gas	\$ 8.36/mmbtu	
Annual fuel cost escalations		
Electric	2.14%/yr	CEC value
Gas	3.75%	CEC value

APPENDIX F

SOLAR RATING AND CERTIFICATION CORPORATION

c/o FSEC • 1679 Clearlake Road • Cocoa, FL 32922-5703 • (407) 638-1537 • Fax: (407) 638-1010

February 4, 1999

Jurg Bieri
Heliodyne, Inc.
4910 Seaport Avenue
Richmond, CA 94804

Dear Jurg:

Enclosed please find a copy of the results of some site-specific TRNSYS runs using the SRCC modeling procedure and the following conditions specified by CSTRR:

- Systems:
 - Heliodyne: 3x8, 65 gal electric (both elements), single wall heat exchanger
 - Heliodyne: 4x8, 65 gal electric (both elements), single wall heat exchanger
 - Heliodyne: 3x8, 50 gal gas, single wall heat exchanger
 - Heliodyne: 4x8, 75 gal gas, single wall heat exchanger
 - Heliodyne: 3x8, 50 gal storage, 50 gal gas, single wall heat exchanger
 - Heliodyne: 4x8, 50 gal storage, 75 gal gas, single wall heat exchanger
- Las Vegas, NV and Phoenix, AZ weather conditions
- Draw of 64 gallons per day with SRCC dual peak profile
- 65 gallon electric backup tanks set at 120°F
- 50 and 75 gallon gas backup tanks set at 120°F
- Collector facing 0°, 30°, 60°, and 90° east at a tilt of 23°
- Water mains temperature varied monthly using F-Chart values for Las Vegas
- Air temperature around the indoor tank calculated as follows to estimate the temperature in a garage: $T_{air} + [(72^\circ\text{F} - T_{air})/3]$

Please note that these are not standard SRCC rating conditions nor standard SRCC annual performance estimate conditions. The attached results are not to be compared to any other performance estimates developed by SRCC. The following systems are not certified under SRCC's OG-300 program so we have quickly assembled an approximate TRNSYS model for them:

- Heliodyne: 4x8, 65 gal electric (both elements), single wall heat exchanger
- Heliodyne: 3x8, 50 gal gas, single wall heat exchanger
- Heliodyne: 4x8, 75 gal gas, single wall heat exchanger
- Heliodyne: 3x8, 50 gal storage, 50 gal gas, single wall heat exchanger
- Heliodyne: 4x8, 50 gal storage, 75 gal gas, single wall heat exchanger

If these systems go through the complete certification process there could be issues that come up which could affect the performance given here.

These results are not to be published nor distributed as official SRCC ratings or performance estimates since they are not based on conditions specified by SRCC.

Please give me a call if you have any questions.

Sincerely,

Jim Huggins
Technical Director

Cc: Bob LeChevalier

Las Vegas Electric

System	Model #	AZ	SRCC	Morning				Evening			
				Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
				DEG MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh
Electric	50 GAL	N/A		11.716	0	10.479	0	11.712	0	10.466	0
	65 GAL	N/A		11.913	0	10.477	0	11.722	0	10.479	0
HD-3X8/65	H3865	-90		3.656	1.002	9.989	1984				
HD-3X8/65	H3865	-60		3.028	1.017	10.022	2174				
HD-3X8/65	H3865	-30		2.642	1.026	10.055	2294				
HD-3X8/65	H3865	0		2.507	1.035	10.07	2335				
HD-4X8/65	H4865	-90		2.729	0.957	10.118	2307				
HD-4X8/65	H4865	-60		2.069	0.962	10.166	2513				
HD-4X8/65	H4865	-30		1.664	0.977	10.218	2643				
HD-4X8/65	H4865	0		1.53	0.983	10.245	2689				

Las Vegas Gas

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	16.759	0	10.474	0.00	16.808	0	10.505	0.00	16.773	0	10.512	0.00
	75 GAL	N/A	18.912	0	10.466	0.00								
HD3X8/50	H3850	-90	11.218	0.851	10.488	4.71								
HD3X8/50	H3850	-60	10.492	0.889	10.491	5.40								
HD3X8/50	H3850	-30	10.147	0.913	10.493	5.72								
HD3X8/50	H3850	0	10.144	0.914	10.494	5.73								
HD3X8/50/50	H3800	0	6.743	1.021	10.244	8.70								
HD4X8/75	H4875	-90	11.298	0.866	10.482	6.77								
HD4X8/75	H4875	-60	10.348	0.901	10.486	7.69								
HD4X8/75	H4875	-30	9.922	0.923	10.489	8.10								
HD4X8/75	H4875	0	9.884	0.924	10.491	8.14								
HD4X8/50/75	H4825	0	7.44	0.965	10.131	10.08								

APPENDIX G

SOLAR RATING AND CERTIFICATION CORPORATION

c/o FSEC • 1679 Clearlake Road • Cocoa, FL 32922-5703 • (407) 638-1537 • Fax: (407) 638-1010

February 4, 1999

Rick Reed
SunEarth, Inc.
4315 South Santa Ana Street
Ontario, CA 91761

Dear Rick:

Enclosed please find a copy of the results of some site-specific TRNSYS runs using the SRCC modeling procedure and the following conditions specified by CSTRR:

- Systems:
 - SunEarth: CP-40 with 50 gal electric
 - SunEarth: CP-40 with 50 gal gas
- Las Vegas, NV and Phoenix, AZ weather conditions
- Draw of 64gallons per day with these profiles:
 - SRCC dual peak
 - Evening weighted
 - Morning weighted
- 50 gallon electric and gas backup tanks set at 120°F
- Collector facing 0°, 30°, 60°, and 90° east at a tilt of 23°
- Water mains temperature varied monthly using F-Chart values for Las Vegas and Phoenix
- Air temperature around the indoor tank calculated as follows to estimate the temperature in a garage: $T_{air} + [(72^{\circ}\text{F} - T_{air})/3]$

Please note that these are not standard SRCC rating conditions nor standard SRCC annual performance estimate conditions. The attached results are not to be compared to any other performance estimates developed by SRCC. The following system is not certified under SRCC's OG-300 program so we have quickly assembled an approximate TRNSYS model for it:

- SunEarth: CP-40 with 50 gal gas

If this system goes through the complete certification process there could be issues that come up which could affect the performance given here.

These results are not to be published nor distributed as official SRCC ratings or performance estimates since they are based on conditions not specified by SRCC.

Please give me a call if you have any questions.

Sincerely,

A handwritten signature in black ink, appearing to read "Jim Huggins", with a stylized, flowing script.

Jim Huggins
Technical Director

cc: Bob LeChevalier

Las Vegas Electric

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU
Electric	50 GAL	N/A	11.716	0	10.479	0	11.712	0	10.466	0	11.722	0	10.479	0
	65 GAL	N/A	11.913	0	10.477	0								
SE CP-40	9211F	-90	6.042	0	10.454	1657	6.358	0	10.442	1563	6.002	0	10.471	1676
SE CP-40	9211F	-60	5.459	0	10.453	1827	5.871	0	10.447	1707	5.333	0	10.472	1872
SE CP-40	9211F	-30	5.098	0	10.451	1933	5.67	0	10.46	1770	4.814	0	10.473	2025
SE CP-40	9211F	0	5.038	0	10.452	1950	5.76	0	10.467	1746	4.554	0	10.472	2101

Phoenix Electric

System	Model #	AZ	SRCC	Morning								Evening			
				Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
				DEG MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh
Electric	50 GAL	N/A		10.777	0	9.624	0	10.782	0	9.618	0	10.788	0	9.63	0
SE CP-40	9211F	-90		5.219	0	9.603	1624	5.803	0	9.612	1458	4.844	0	9.624	1743
SE CP-40	9211F	-60		4.669	0	9.603	1785	5.337	0	9.612	1595	4.198	0	9.624	1933
SE CP-40	9211F	-30		4.298	0	9.602	1894	5.067	0	9.614	1675	3.676	0	9.623	2085
SE CP-40	9211F	0		4.195	0	9.605	1925	5.043	0	9.618	1683	3.403	0	9.625	2166

Las Vegas Gas

System	Model #	AZ	SRCC	Morning				Evening							
				Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
				DEG MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	16.759	0	10.474	0.00	16.808	0	10.505	0.00	16.773	0	10.512	0.00	
	75 GAL	N/A	18.912	0	10.466	0.00									
SE CP-40-G	9211X	-90	9.289	0	10.424	7.41	9.693	0	10.434	7.03	9.409	0	10.473	7.31	
SE CP-40-G	9211X	-60	8.521	0	10.421	8.17	9.04	0	10.433	7.68	8.547	0	10.469	8.17	
SE CP-40-G	9211X	-30	8.051	0	10.415	8.63	8.779	0	10.445	7.95	7.899	0	10.472	8.82	
SE CP-40-G	9211X	0	7.985	0	10.417	8.70	8.932	0	10.451	7.81	7.565	0	10.47	9.15	

Phoenix Gas

System	Model #	AZ	SRCC	Morning								Evening			
				Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
				DEG MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A		15.571	0	9.621	0.00	15.613	0	9.65	0.00	15.57	0	9.654	0.00
SE CP-40-G	9211X	-90		8.241	0	9.567	7.26	9.002	0	9.594	6.54	7.922	0	9.612	7.59
SE CP-40-G	9211X	-60		7.535	0	9.567	7.97	8.391	0	9.588	7.14	7.091	0	9.608	8.42
SE CP-40-G	9211X	-30		7.062	0	9.565	8.44	8.075	0	9.588	7.46	6.43	0	9.609	9.08
SE CP-40-G	9211X	0		6.959	0	9.57	8.55	8.103	0	9.594	7.44	6.075	0	9.609	9.44

APPENDIX H

SOLAR RATING AND CERTIFICATION CORPORATION

c/o FSEC • 1679 Clearlake Road • Cocoa, FL 32922-5703 • (407) 638-1537 • Fax: (407) 638-1010

February 4, 1999

Tom Bohner
Sun Systems, Inc.
15716 N. 76th Street
Scottsdale, AZ 85260

Dear Tom:

Enclosed please find a copy of the results of some site-specific TRNSYS runs using the SRCC modeling procedure and the following conditions specified by CSTRR:

- Systems:
 - Sun Systems: 4850
 - Sun Systems: 4850G
- Las Vegas, NV and Phoenix, AZ weather conditions
- Draw of 64gallons per day with these profiles:
 - SRCC dual peak
 - Evening weighted
 - Morning weighted
- 50 gallon electric and backup tanks set at 120°F
- Collector facing 0°, 30°, 60°, and 90° east at a tilt of 23°
- Water mains temperature varied monthly using F-Chart values for Las Vegas and Phoenix
- Air temperature around the indoor tank calculated as follows to estimate the temperature in a garage: $T_{air} + [(72^{\circ}\text{F} - T_{air})/3]$

Please note that these are not standard SRCC rating conditions nor standard SRCC annual performance estimate conditions. The attached results are not to be compared to any other performance estimates developed by SRCC.

These results are not to be published nor distributed as official SRCC ratings or performance estimates since they are not based on conditions specified by SRCC.

Please give me a call if you have any questions.

Sincerely,

A handwritten signature in black ink, appearing to read "Jim Huggins", with a stylized flourish at the end.

Jim Huggins
Technical Director

cc: Bob LeChevalier

Las Vegas Electric

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh
Electric	50 GAL	N/A	11.716	0	10.479	0	11.712	0	10.466	0	11.722	0	10.479	0
	65 GAL	N/A	11.913	0	10.477	0								
SS- 4850	9701A	-90	6.456	0	10.46	1537	6.954	0	10.451	1391	6.829	0	10.469	1433
SS- 4850	9701A	-60	5.921	0	10.46	1694	6.586	0	10.459	1501	6.227	0	10.47	1610
SS- 4850	9701A	-30	5.612	0	10.458	1784	6.535	0	10.474	1521	5.713	0	10.473	1761
SS- 4850	9701A	0	5.585	0	10.458	1792	6.764	0	10.477	1454	5.393	0	10.475	1856

Las Vegas Gas

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	16.759	0	10.474	0.00	16.808	0	10.505	0.00	16.773	0	10.512	0.00
	75 GAL	N/A	18.912	0	10.466	0.00								
SS- 4850G	9901A	-90	9.799	0	10.428	6.90	10.557	0	10.475	6.21	10.279	0	10.577	6.58
SS- 4850G	9901A	-60	9.109	0	10.425	7.59	10.067	0	10.462	6.69	9.487	0	10.605	7.40
SS- 4850G	9901A	-30	8.715	0	10.419	7.97	10.023	0	10.469	6.74	8.804	0	10.634	8.12
SS- 4850G	9901A	0	8.723	0	10.425	7.97	10.416	0	10.496	6.38	8.388	0	10.671	8.59

Phoenix Gas

System	Model #	AZ	SRCC				Morning				Evening					
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save		
			DEG	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	15.571	0	9.621	0.00	15.613	0	9.65	0.00	15.57	0	9.654	0.00		
SS- 4850G	9901A	-90	8.86	0	9.57	6.65	10.247	0	9.625	5.33	8.573	0	9.777	7.15		
SS- 4850G	9901A	-60	8.227	0	9.568	7.28	9.821	0	9.62	5.75	7.763	0	9.806	8.00		
SS- 4850G	9901A	-30	7.829	0	9.562	7.67	9.709	0	9.629	5.88	7.033	0	9.839	8.77		
SS- 4850G	9901A	0	7.781	0	9.569	7.72	9.916	0	9.65	5.70	6.579	0	9.883	9.28		

APPENDIX I

SOLAR RATING AND CERTIFICATION CORPORATION

c/o FSEC • 1679 Clearlake Road • Cocoa, FL 32922-5703 • (407) 638-1537 • Fax: (407) 638-1010

February 4, 1999

Griff Carrison
Thermal Conversion Technologies
PO Box 3887
Sarasota, FL 34230

Dear Griff:

Enclosed please find a copy of the results of some site-specific TRNSYS runs using the SRCC modeling procedure and the following conditions specified by CSTRR:

- Systems:
 - Thermal Conversion Technologies: PT-40-CN
 - Thermal Conversion Technologies: PT-40-CN-G
- Las Vegas, NV and Phoenix, AZ weather conditions
- Draw of 64gallons per day with these profiles:
 - SRCC dual peak
 - Evening weighted
 - Morning weighted
- 50 gallon electric and gas backup tanks set at 120°F
- Collector facing 0°, 30°, 60°, and 90° east at a tilt of 23°
- Water mains temperature varied monthly using F-Chart values for Las Vegas and Phoenix
- Air temperature around the indoor tank calculated as follows to estimate the temperature in a garage: $T_{air} + [(72^{\circ}\text{F} - T_{air})/3]$

Please note that these are not standard SRCC rating conditions nor standard SRCC annual performance estimate conditions. The attached results are not to be compared to any other performance estimates developed by SRCC.

These results are not to be published nor distributed as official SRCC ratings or performance estimates since they are based on conditions not specified by SRCC.

Please give me a call if you have any questions.

Sincerely,

A handwritten signature in black ink, appearing to read "Jim Huggins", with a stylized, flowing script.

Jim Huggins
Technical Director

cc: Bob LeChevalier

Las Vegas Electric

System	Model #	AZ	SRCC	Morning				Evening							
				Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
				DEG MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh
Electric	50 GAL	N/A		11.716	0	10.479	0	11.712	0	10.466	0	11.722	0	10.479	0
	65 GAL	N/A		11.913	0	10.477	0								
PT-40-CN	9502C	-90		5.138	0	10.462	1924	5.38	0	10.456	1854	4.991	0	10.481	1975
PT-40-CN	9502C	-60		4.466	0	10.46	2121	4.782	0	10.459	2030	4.236	0	10.481	2197
PT-40-CN	9502C	-30		4.037	0	10.461	2247	4.473	0	10.467	2123	3.664	0	10.483	2365
PT-40-CN	9502C	0		3.94	0	10.462	2275	4.522	0	10.475	2111	3.405	0	10.484	2441

Phoenix Electric

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh	MMBTU	MMBTU	MMBTU	kWh
Electric	50 GAL	N/A	10.777	0	9.624	0	10.782	0	9.618	0	10.788	0	9.63	0
PT-40-CN	9502C	-90	4.34	0	9.611	1884	4.807	0	9.613	1751	3.923	0	9.632	2016
PT-40-CN	9502C	-60	3.715	0	9.61	2067	4.247	0	9.617	1916	3.212	0	9.633	2224
PT-40-CN	9502C	-30	3.292	0	9.612	2191	3.903	0	9.622	2018	2.674	0	9.633	2382
PT-40-CN	9502C	0	3.168	0	9.614	2228	3.84	0	9.624	2038	2.432	0	9.636	2454

Las Vegas Gas

System	Model #	AZ	SRCC				Morning				Evening			
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save
			DEG	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	16.759	0	10.474	0.00	16.808	0	10.505	0.00	16.773	0	10.512	0.00
	75 GAL	N/A	18.912	0	10.466	0.00								
PT-40-CN-G	9806C	-90	7.987	0	10.427	8.71	8.262	0	10.432	8.45	8.043	0	10.477	8.69
PT-40-CN-G	9806C	-60	7.111	0	10.425	9.59	7.462	0	10.427	9.25	7.082	0	10.478	9.65
PT-40-CN-G	9806C	-30	6.569	0	10.423	10.13	7.101	0	10.423	9.60	6.362	0	10.477	10.37
PT-40-CN-G	9806C	0	6.49	0	10.427	10.21	7.254	0	10.427	9.46	6.025	0	10.476	10.70

Phoenix Gas

System	Model #	AZ	SRCC	Morning						Evening					
			Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	Q aux	Q Par	Q Del	Q Save	
			DEG	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU	MMBTU
Gas	50 GAL	N/A	15.571	0	9.621	0.00	15.613	0	9.65	0.00	15.57	0	9.654	0.00	
PT-40-CN-G	9806C	-90	7.006	0	9.577	8.51	7.59	0	9.576	7.93	6.644	0	9.621	8.88	
PT-40-CN-G	9806C	-60	6.189	0	9.573	9.32	6.861	0	9.568	8.65	5.715	0	9.616	9.81	
PT-40-CN-G	9806C	-30	5.678	0	9.581	9.84	6.479	0	9.569	9.03	5.032	0	9.623	10.50	
PT-40-CN-G	9806C	0	5.551	0	9.585	9.97	6.492	0	9.579	9.03	4.715	0	9.628	10.82	

APPENDIX J

FREEZE TEST REPORT - ICS COLLECTOR

INTRODUCTION

CSTRR in partnership with Pulte Homes, Nevada Power Co., the University of Nevada and the Nevada State Energy Office received a Financial Assistance award from the US Dept. of Energy Golden for the marketing of solar water heating (SWH) systems in the Las Vegas and Phoenix markets. In response to this award a pre-qualification & test plan was prepared for the selection of the best-qualified SWH systems. In this plan, systems to be used for this marketing effort were to be the most economical and reliable, SRCC certified, products. The plan provided for a performance/economic analysis program to compare the leading products. The results have previously been reported. Based on the analysis and an on-site review of the products and their respective manufacturers, the Integral Collector Storage (ICS) and indirect designs were selected as the leading design options for this marketing program. One unresolved issue with the ICS design was a concern regarding its ability to survive the temperature extremes of Las Vegas (Freezing in Phoenix was not considered to be an issue since the lowest recorded temperature in Phoenix is 16 °F). For this reason, a freeze test of this product was included in the test plan.

TEST OBJECTIVE

In accordance with the test plan for the SWH initiative, a freeze test of the ICS design will be conducted to demonstrate the integrity of the collector and the hot water supply to the residence under typical low temperature conditions as has been historically experienced in the Las Vegas.

BACKGROUND

The requirement for a freeze test of the ICS design was based on historical data for Las Vegas. According to the National Weather Service, Las Vegas experienced three days when the temperature dropped to 8 °F. This temperature occurred in 1937 and 1963. The 1937 temperatures were particularly severe as the temperature dropped below 20 °F for eight successive days. The Weather Service provided the daily lows for the eight days in 1937 and for four of those days was also able to provide the daily high temperatures. The recorded temperatures were as follows:

	<u>Daily Low - °F</u>	<u>Daily High - °F</u>
1/20/37	17	
1/21/37	13	28
1/22/37	9	31
1/23/37	14	35
1/24/37	15	31
1/25/37	8	
1/26/37	10	
1/27/37	12	
1/28/37	18	
1/13/63	8	

During the past decade, the most severe lows occurred in 1990 when a low temperature of 12.8 °F was observed on the night of December 22/23. A complete hourly record for the month of December 1990 was provided by the Nevada Power Co., see Attachment #1.

Given these historic low temperature conditions for Las Vegas, there are three concerns that must be addressed, these are:

1. Water heater recovery rate
2. Hot water interruption
3. SWH rupture

Water heater recovery rate - Under moderate subfreezing conditions encountered during most Las Vegas winters, the insulation of the ICS will be inadequate to prevent the loss of most heat from water stored in the collector. Thus, the collector water can be expected to approach 32 °F. Since the ICS collector serves as the input to the conventional water heater, the collector water at near 32 °F would be about 15 – 20 °F below typical water main temperatures for the winter months in Las Vegas. Thus the water heater recovery rates would be reduced by about 30%. This could be a cause for concern and possible homeowner complaints.

Hot water interruption - Under abnormal freezing conditions, such as occurred in 1990, there is a concern that the manifolds in the collector could freeze. Should ice form in the collector manifolds, flow through the collector would be affected. SRCC rules require a manually operated by-pass valve and it would be necessary to employ this feature to obtain hot water. The homeowner would have to be instructed to open this by-pass valve if hot water is not available.

SWH rupture – Under the most severe low temperature conditions, such as occurred in 1937 and 1963, there is the possibility of a hard freeze in the collector and even a rupture of collector components. This of course would require the replacement of the collector. Hot water would not be affected, as SRCC rules require the installation of valves to isolate and by-pass the collector. However, the collector would have to be replaced.

TEST PROCEDURE

The Sun Systems ICS collector was selected for the freeze test. This collector, model # 4850, measures approximately 4 ft. x 8 ft. Inlet and outlet connectors of the collector penetrate the back face of the collector at one end with a spacing of about 3.5-ft. For this test the collector was mounted on a wood test fixture having wood sheathing attached to a wood frame at approximately 45°. After the collector was mounted on the test fixture, horizontal copper manifolds were installed with hand valves such that the valves were easily accessible at the back of the test fixture. The top manifold was about 6" long and the lower manifold was about 3' long. Heater tape was wrapped around both manifolds to permit the application of heat for the prevention of freezing since these were expected to be the most vulnerable to freezing. ¾" pipe insulation was installed over the heater tape to simulate typical pipe insulation used in residential construction.

Seven iron - constantin temperature sensors were attached to components of the collector. The numbering and locations of these sensors was as follows:

- Sensor #1 - Lower manifold inside the collector @ the external manifold end of the collector
- Sensor #2 - Lower manifold inside the collector opposite the external manifold end of the collector
- Sensor #3 - Upper manifold inside the collector opposite the external manifold end of the collector
- Sensor #4 - Ambient
- Sensor #5 - Lower external manifold
- Sensor #6 - Upper external manifold
- Sensor #7 - Absorber tube @ approximate center of the collector

The placement of these sensors was intended to permit the monitoring of the external manifolds, the internal manifolds, the 4" absorber tubes and the ambient temperature in the cold chamber. A meter was used to record the thermocouple outputs and a variac was used to provide a variable power source for the heater tape.

A food freezer at the Nevada Test Site (NTS) was selected for the test chamber. The temperature of this chamber has an operating range of 3-4 °F at the control temperature. The temperature range of the chamber can be controlled from room temperature to sub-zero temperatures and therefore was considered adequate for this test.

The test setup was transported to the NTS on February 11 and placed on a movable platform for easy movement into the test chamber. Prior to the start of the test, the collector was filled and flushed with fresh water to ensure the maximum amount of water in the collector. The water temperature was 55 °F which is two degrees less than the lowest recorded Las Vegas winter water temperature as reported by the Las Vegas Water District.

Immediately after filling the collector with the fresh water, the collector was moved into the test chamber, which was preset, to 5 °F. This temperature was selected as it represented the coldest

recorded temperature for Las Vegas (8 °F) minus an additional 3 degrees to compensate for night sky radiation losses. Temperature readings for the seven sensors were taken at approximately 15-minute intervals. The results are reported in Attachment #2. After approximately one hour, freezing temperatures were recorded at the lower external manifold, sensor #5. Voltage was applied to the heater tape to prevent ice formation in this manifold. Six hours after the collector was placed in the test chamber all the internal sensors recorded freezing temperatures and the test was terminated to prevent damage to the collector due to ice formation.

Due to the short period over which the internal components reached freezing temperatures, it was decided to evaluate the collector tolerance to more recent weather conditions such as those which occurred on December 22/23, 1990. This second test was performed February 17. Prior to placing the collector in the test chamber, the collector was flushed with fresh water and the collector was stabilized at 55 °F. After placing the collector in the chamber, readings were again taken at approximately 15-minute intervals. The results are reported in Attachment #3. Column #1 and #2 in this attachment represent the time and temperature for actual temperatures recorded by the National Weather Service for December 22/23, 1990. Column #3 represents the time at which recordings were taken during this second freeze test. The seven sensor recordings follow in the remaining columns.

As with the first test, the lower external manifold was the first collector component to reach freezing temperatures. This occurred approximately 4 hours into the test and at that time voltage was applied to the heater tape to prevent icing of the manifold. Near the conclusion of the test as all the internal components reached freezing temperatures, additional voltage was applied to the heater tape to ensure complete thawing of the manifolds so that possible ice blockages in the collector could be studied immediately after removing the collector from the test chamber.

The need for this ice blockage test became apparent when the twelve-hour test period ended. At the 12th hour the collector was removed from the test chamber and both valves were opened to determine if water could flow through the collector without pressurization. When only about 1-2 gallons of water flowed from the lower manifold, it was assumed that ice had formed in the collector. Next, the water supply line was attached to the upper manifold and line pressure was applied. Within seconds, the internal obstructions were removed and full flow occurred even after the line pressure was removed.

FINDINGS

Find #1 -Freeze tolerance @ 5 °F simulating conditions which occurred in January 1937

This test demonstrated that extreme low temperatures for Las Vegas are likely to cause the internal manifolds to reach freezing temperatures within 4 hours and therefore since these extreme conditions are likely to occur for more than 12 hours on a typical winter day, the presence of significant ice formation can be expected. Without a destructive test insufficient evidence is available to determine the extent of damage which might result. However, given the ice blockages which occurred in Test #2, it is reasonable to assume that serious ice formation is likely to occur in the internal manifolds and water flow would be interrupted through the collector pending the availability of sunshine or non-freezing daytime temperatures.

Find #2 – Freeze tolerance under simulated conditions recorded for December 22/23, 1990

This test demonstrated the marginal freeze tolerance of this collector under less severe conditions, such as those which occurred in the 1990 decade. Clearly, all the internal components are likely to reach freezing temperatures, but given the slow rate of ice formation, water line pressure should be sufficient to remove any blockages and thus ensure a flow of fresh hot water into the residence.

Finding #3 – Water heater recovery impacts

Both tests demonstrated the rapid loss of water temperatures in the ICS collector and when this collector experiences subfreezing temperatures; the collector water is likely to approach 32 °F. Given this inlet temperature to the water heater and the volume of water in the collector, the homeowner will experience a reduction in the availability of hot water until either the sun rises and heats the collector (this should occur in a few daylight hours on a sunny day) or the homeowner uses the approximate 40 gallons stored in the collector.

Finding #4 – External manifolds

Both tests have shown that external, insulated, manifolds exposed to freezing temperatures will freeze within normal nighttime hours. Unexposed manifolds that protrude from the underside of the collector should not be a concern.

Finding #5 – Freezing issues in Phoenix

Given that the historic low recorded in Phoenix was 16 °F, there are no concerns with obstruction of flow rates or damage to the collector under the most severe conditions of Phoenix. Minimal effects on the hot water heater recovery rates could occur, but these should be very minimal.

CONCLUSIONS

These freeze tests demonstrated the sensitivity of the ICS when subjected to subfreezing temperatures experienced in Las Vegas. Under most winter conditions, including some excursions from typical lows such as that experienced the night of December 22/23, 1990, these tests have provided confidence that the collector is capable of withstanding these temperatures without permanent damage and/or the interruption of hot water. However, these tests have also provided evidence that water temperatures in the collector on the typical cold winter day in Las Vegas will reach near freezing temperatures thereby impacting the water heater recovery rate.

Temperatures in Las Vegas would have to reach the extremes experienced in 1963 and 1937 before there would be a concern with the interruption of hot water or even permanent damage to the collector.

It should be noted that the residential solar hot water user will always have the protection of the by-pass valves that are installed in every system under SRCC rules in the event that hot water is

interrupted or a leak in the collector occurs. However, it will be important to prominently display instructions to the homeowner on the procedures for activating the by-pass.

The effect of winter conditions on the performance of the ICS system is not an issue as the analysis previously conducted under this contract considered average yearly temperature conditions. While the annual energy savings will fluctuate, over the system lifetime the performance should meet predicted amounts.

Any ICS collector system used in the Las Vegas market must not have any exposed external manifolds as these tests have shown that average winter temperatures could cause icing of the internal manifolds.

Finally, it should be noted that the ICS collector in the Phoenix market will be minimally impacted by the most severe winter conditions experienced in Phoenix.

RECOMMENDATION

An ad hoc technical review committee has reviewed the findings of this test report and concur that the conclusions are reasonable and therefore, this group of technical experts conclude that this collector is suitable for typical Las Vegas climatic conditions including reasonable temperature excursions such as those experienced in 1990.

MEMBERS OF THE AD HOC TECHNICAL REVIEW COMMITTEE

Robert Le Chevalier – CSTRR, Project Director
Dr. Byard Wood – University of Nevada, Reno
Dr. Robert Boehm – University of Nevada, Las Vegas
Dale Green – Nevada Power Co.
Rod Mahoney – Sandia National Labs, Albuquerque
Russ Hewitt – National Renewable Energy Lab

ATTACHMENT #1

RECORDED TEMPERATURES DURING THE COLDEST MONTH THIS DECADE

1-Dec-90	37.8	36.1	35.5	34.7	33.2	33.4	32.2	34.2	40.1	44.9	48.6	53.6	57.1	58.3	59.4	58.6	56.3	52.7	49.6	46.3	45.3	43.7	41.8	42.7
2-Dec-90	41.5	39.3	38.9	40.4	40.6	45.3	48.6	51.2	54.6	55.7	59.1	61	61.1	61.4	60.6	58.8	56.3	53	50.4	49.6	47.9	42.3	41.9	43.3
3-Dec-90	42.2	39.3	36.9	37.7	38.9	37.2	36.3	37.3	42.7	48.5	51.7	54.4	56.3	58.2	58.3	56.6	54.5	52.7	50.2	46	44	43.6	41.1	39.8
4-Dec-90	38.6	37.2	36.3	36.6	35.7	34.7	33.2	33.1	39.2	43.3	50.7	54.6	57	59.1	59.2	58	56.2	52.9	50.6	46.4	44.3	42.7	41.6	39.6
5-Dec-90	39	38.9	38.8	37.3	36.3	36.3	36.7	36.5	36.8	41.9	48.2	53.4	57.4	59.5	60.4	59.8	57.9	52.1	50.2	48.3	46.7	45.8	43.5	41.5
6-Dec-90	39.6	39.5	37.9	39.7	38.6	39.6	39.1	38.8	43.4	51.3	54.5	57.1	58.4	59.3	59.5	58.4	55.6	53.5	49.4	45	41.9	41.9	40.8	37.4
7-Dec-90	36.6	36.5	35.2	34.3	32.9	32.4	32.4	32.4	37.6	43.6	48.3	51	54	56.1	56.4	56.5	54.5	51.2	48.6	45.2	42.9	41	38.9	36.6
8-Dec-90	36.3	34.6	34.3	33.4	32.4	32.1	32.1	33.3	38.3	45	48	53	56.3	58.4	59.7	59.8	56.5	53.1	48.4	45.8	42.1	40.9	39.1	39.7
9-Dec-90	37.8	35.5	35.5	34.7	34.3	32.8	33.3	33.6	39.6	43.7	49.4	54.5	58.4	60.4	62.2	61.8	58.6	54.9	50.7	46.1	44	42.9	41.3	40.2
10-Dec-90	38.1	37.2	36.3	35.3	35	33.6	33.1	33.9	37.7	43.1	49.1	54.3	57.7	59.8	61.5	60.6	56.3	56.1	52.3	47.9	44.6	43.1	41.4	41.1
11-Dec-90	40.1	39.3	38.6	36.6	37.1	36.9	36.9	36.9	39.9	45.3	49.3	52.2	54.7	58.4	60.7	60.7	58.6	57.6	55.9	55.3	54.8	55.2	54.2	53.5
12-Dec-90	53.5	55.2	52.6	52.3	51.2	50.5	50.3	50.3	52	54.3	56.1	56.3	56.4	57.1	56.8	56.3	55.3	54.5	52.9	51.4	49.1	48	44.4	43.2
13-Dec-90	41.8	40.9	39.7	39.1	37.7	37.4	37	37.8	38.9	42.4	46.8	50.2	52.8	55	56.6	58.4	56	54.8	52.8	52.2	51.1	48.2	47.2	46.4
14-Dec-90	46	43.7	42.9	42.7	43.4	39	39.1	41.4	44.2	46.6	47.9	50.1	51.4	51.3	51.2	50.4	48	46.6	45.2	42.6	39	36.3	34.7	33.4
15-Dec-90	33.3	31.9	30.5	30.1	28.5	28.3	28	29.3	31.8	38.1	42.2	46.3	48.1	50	50.6	49.9	48.1	45.8	44.5	43.2	39.7	39.3	38.6	36.9
16-Dec-90	39	40	39.2	41.1	40.2	39.8	39.4	40.3	41.6	46.3	49.7	51.7	51.6	48.4	49.1	51.5	50.2	49.4	48.6	48.4	47.8	47	45.8	45.4
17-Dec-90	44.9	44.3	42.9	41.8	40.1	40.4	41.5	41.9	44	46	48.6	50.3	51.4	52.5	53.3	52.2	51.1	48.4	47.9	43.7	42.7	39.7	38.1	36.8
18-Dec-90	35.5	35.5	34.2	32.5	31.9	32.3	33	32.6	35.1	38.6	42.3	45.4	47.6	49.6	50.7	49.5	48.1	46.5	43.2	40.9	40.8	41	38.9	38.3
19-Dec-90	36.7	37.1	43.4	42.5	48.1	47.9	47.2	47	48.1	50.2	52	52.5	55.3	53.9	53.7	52.1	50.3	49.4	48.5	46.8	46	45	44.3	42.6
20-Dec-90	41.6	40.1	39	38.3	34	33.6	33.4	33.5	33.3	35	36.7	37.3	38.2	37.9	37.3	34.5	33.4	32.9	32.3	32.5	32.5	30.6	30.3	28.8
21-Dec-90	27.5	25.8	25.8	27.8	27.9	27.5	27.1	27.3	28	29.8	32.2	32.8	32.8	33.7	33.9	33.7	32.1	30.3	29.9	29.7	28.3	25.6	25.7	24
22-Dec-90	24.4	22.6	21	21.1	20.7	19.8	19.7	20.3	22.2	24.4	26.8	28.4	30.2	31.1	33	32.1	29.6	28.4	27	24.8	22.6	21.5	19.5	19.5
23-Dec-90	17.7	16.1	16.5	14.9	14.8	14.8	12.8	13.1	17.8	20.9	23.7	26.1	27.3	29.3	30.9	31.7	30.6	30.2	28.1	27	26	24.5	22.6	22.7
24-Dec-90	23.3	21.6	20.3	19.3	19.2	18.8	16.7	16.6	20.8	24.3	28.4	31.9	34.9	36.8	37.8	38.6	37.4	34.8	32.4	29.3	27.9	26.7	26.5	23.8
25-Dec-90	20.5	21.1	21.2	22.9	21.7	20.6	21.8	22.6	25	30.7	34.8	38.3	41.1	42.9	45.7	45.3	42.4	41.1	37.5	35.5	32	31.8	30.6	30.1
26-Dec-90	29.7	28.4	26.2	24.7	24.2	21.8	21.8	23.6	28.6	30.6	36.3	40.8	43.9	46.5	48.4	48.6	46	43.7	41.7	40.9	39.2	37.8	37.8	33.5
27-Dec-90	31.4	30.1	28.2	28.3	26.4	25.6	26.4	26.7	29.1	36.3	40.1	41.7	43.8	45.4	46.2	46.3	45	42.3	39.7	35.7	34.5	32.1	30.1	29.4
28-Dec-90	27.9	27.5	25.1	24.9	24.4	23.9	24.2	24.4	28.2	31.9	36.6	39.7	42.8	44.3	45.7	45.8	44.2	43.1	40.7	37.1	34.8	32.9	31.7	31.1
29-Dec-90	31.4	30.8	30.1	30.4	30.3	30.1	30.9	32.4	35.2	41.1	46.8	48.2	48.2	48.2	47.8	46.3	42.8	40.1	37.8	36.3	35.1	33.8	33	32.1
30-Dec-90	29.7	27.3	26.4	25.8	22.1	21.8	20.2	19.5	22	27.8	31.1	33.1	35.5	37.2	38.3	39.4	37.7	35.1	32.7	30.1	27	24.8	24.7	24.2
31-Dec-90	22.9	20.1	19.8	20.6	19.3	18	18	21.4	24.5	27.7	32.9	38.4	42.6	44.7	46.1	47.1	45.5	41.8	38.1	36.5	32.7	30.9	28.8	29.1

Minimum - 12.8 F on Dec. 23

ATTACHMENT #2

COLLECTOR COMPONENT TEMPERATURES DURING TESTS SIMULATING HISTORIC LOW TEMPERATURES OCCURRING IN 1937 & 1963 (TEMP. READINGS IN DEG. C)

<u>Time</u>	<u>Sensor #1</u>	<u>Sensor #2</u>	<u>Sensor #3</u>	<u>Sensor #4</u>	<u>Sensor #5</u>	<u>Sensor #6</u>	<u>Sensor #7</u>
10:45	11.8	11.7	11.4	-16.8	7.9	10.1	11.7
10:49	10.7	10.8	10.2	-16	6.4	9.5	10.7
10:57	9.6	9.8	9	-14.1	4.5	7.6	9.1
11:15	8.6	8.5	7.9	-14.7	0.8	4.7	8.1
11:25	8.4	8.1	7.6	-14.2	-0.3	3.9	8.1
11:35	8.2	7.6	7.4	-16.3	5.2	4.8	7.8
11:45	7.7	7.1	6.9	-17.6	2.3	4.5	7.4
12:00	7.3	6.3	6.7	-15.7	1.1	3.6	6.9
12:15	6.8	5.8	6.3	-17.8	0.5	3.2	6.6
12:30	6.4	5.3	6	-13.7	0.5	2.9	6.2
12:43	6.1	4.7	5.7	-15	0.4	2.5	6
1:02	5.4	4	5.1	-15.1	0.5	2.2	5.4
1:15	4.9	3.3	4.8	-15.4	0.5	1.9	5.1
1:30	4.5	2.5	4.2	-17	1.3	2.1	4.8
2:00	3.6	1.4	3.5	-16.5	1.4	2	4.1
2:15	3.1	1	3	-15	1.3	1.8	3.6
2:30	2.5	0.6	2.8	-15.1	1.5	1.6	3.2
2:45	2.2	0.2	2.4	-15.8	1.5	1.4	2.9
3:00	1.7	-0.1	1.9	-16	1.5	1.1	2.6
3:15	1.3	-0.6	1.6	-15.4	1.5	0.8	2.2
3:30	0.8	-0.9	1.2	-13.6	1.5	0.6	1.8
3:45	0.4	-1.3	0.6	-16.7	1.5	0.3	1.5
4:00	0.2	-1.6	0.4	-16.5	1.5	0.1	1.3
4:15	0	-1.9	0.2	-16.4	1.5	0	1
4:30	-1.2	-0.1	-0.1	-16.4	2.7	0.3	0.7
4:45	-0.6	-0.7	-0.5	-15.8	2.9	0.4	0.4
5:00	-0.8	-0.8	-0.6	-14.8	3	0.3	0.1

Heater activated

ATTACHMENT #3

RECORDED TEMPERATURES DURING A FREEZE TEST AT SIMULATED TEMPERATURES FOR 12-22/23-90

TIME OF DAY RECORDED		TIME	SENSOR						
12-22/23-90	TEMP - C	2/17/99	#1	#2	#3	#4	#5	#6	#7
9:00 PM	-5.2	9.47 AM	12.6	12.9	12.1	-2.2	24.9	13.8	12.9
		10.01 AM	11.5	12	10.3	-2.8	12.5	10.8	10.6
		10.15 AM	10.9	11.5	9.7	-4.5	9.8	8	10.2
		10.30 AM	10.4	11.2	9.3	-5.9	7.5	6.6	10.1
10:00 PM	-5.8	10.49 AM	10	10.6	9.1	-3.9	6	5.8	9.6
		11.00 AM	10	10.5	9	-5.2	5.3	5.5	9.5
		11.15 AM	9.8	10.2	8.9	-4.8	4.5	5.1	9.5
		11.30 AM	9.4	9.9	8.6	-3.9	3.8	4.9	9.2
11:00 PM	-6.9	11.45 AM	9.2	9.4	8.2	-6.5	3	4.6	8.9
		12.00 AM	8.7	8.9	7.8	-6.8	2.3	4.3	8.5
		LUNCH							
		12.30 PM	8.2	8.2	7.4	-6.6	1.2	3.8	8
12:00 PM	-6.9	1.00 PM	7.8	7.6	7.1	-5.4	0.8	3.5	7.6
		1.15 PM	7.5	7.3	6.8	-4.8	0.7	3.2	7.3
		1.30 PM	7.3	7	6.7	-5.8	0.6	2.9	7.2
		1.45 PM	7	6.7	6.4	-5.8	0.5	2.7	7
1:00 AM	-7.9	2.00 PM	6.4	5.4	5.6	-6.7	-0.1	2.5	6.2
		2.15 PM	6.2	5.6	5.5	-10.1	-0.4	2.2	6
		2.30 PM	5.8	5.2	5.2	-8.3	-0.3	2.1	5.7
		2.45 PM	5.6	4.9	4.9	-9.3	-0.4	1.9	5.6
2:00 AM	-8.8	3.00 PM	5.3	4.5	4.7	-9.8	-0.5	1.7	5.4 Heater activated
		3.15 PM	5.1	4.1	4.5	-9.9	0.6	2	5.1 on external manifolds
		3.30 PM	4.8	4	4.3	-10	0.6	2.1	5
		3.45 PM	4.5	3.6	4	-7.6	0.6	2.1	4.6
3:00 AM	-8.6	4.00 PM	4.1	2.9	3.6	-9.7	0.5	2	4.2
		4.15 PM	3.7	2.4	3.3	-9.1	0.4	1.7	3.8

4:00 AM	-9.5	4.30 PM	3.4	1.9	3	-9.2	0.4	1.5	3.5
		4.45 PM	3.1	1.7	2.6	-9.6	0.4	1.3	3.1
		5.00 PM	2.5	1.3	2.2	-11.5	0.3	0.9	2.7
		5.15 PM	2.1	1	1.8	-10.4	0.4	0.8	2.5
5:00 AM	-9.6	5.30 PM	1.9	0.8	1.7	-11	0.4	0.6	2.3
		5.45 PM	1.6	0.5	1.3	-12.6	0.4	0.4	2.1
		6.00 PM	1.3	0.3	1.1	-12	0.3	0.2	1.9
		6.15 PM	1	0	0.8	-12.1	0.3	0	1.5 Heater voltage increased
6:00 AM	-9.6	Dinner							
7:00 AM	-10.7	7.22 PM	0.1	-1.1	-0.1	-12.2	1.5	0.2	0.8
		7.30 PM	0.1	-1.2	-0.2	-12.4	1.6	0.2	0.7
		7.45 PM	-0.1	-1.4	-0.4	-12.4	1.6	0.1	0.5
		8.00 PM	-0.3	-1.6	-0.6	-12	1.7	0	0.3
8:00 AM	-10.5	8.15 PM	-0.5	-1.8	-0.6	-11.7	1.8	0	0.1
		8.30 PM	-0.6	-1.9	-0.7	-11.2	1.9	0	0.1
		8.45 PM	-0.8	-0.9	-0.9	-11.8	2	0.1	-0.1
		9.00 PM	-0.8	-0.9	-1	-11.1	2.1	0	-0.3 Heater voltage increased
9:00 AM	-7.8	9.15 PM	-0.9	-0.6	-1.1	-11.7	18.5	4.3	-0.4
		9.30 PM	-1	-0.6	-1.2	-10.2	47.1	12.5	-0.6
		9.45 PM	-1	-0.6	-1.3	-11.6	75.4	23.1	-0.6

Freeze test terminated after 12 hours; collector was removed from the chamber

Inlet & outlet valves opened to test water flow through the collector.

Limited flow resulted. Water hose was attached to the inlet and line pressure was applied causing full flow through the collector.

Sensor #1 - Lower left manifold, inside collector

Sensor #2 - Lower right manifold, inside collector

Sensor #3 - Upper right manifold, inside collector

Sensor #4 - Ambient

Sensor #5 - Lower, external manifold

Sensor #6 - Upper, external manifold

Sensor #7 - Absorber tube @ approx. center of collector (inside collector)

APPENDIX K

MARKETING & BUSINESS PLAN

SOLAR WATER HEATING (SHW) PROJECT

Builder/Utility Profiles

Pulte Homes has been a US homebuilder since 1941 and currently constructs homes in over 40 cities with additional production in Puerto Rico and Mexico. Pulte has long been one of the leading builders in this country and in 1997 was named "Builder of the Year". With 15,323 homes built in '97 and 20,359 in '98, Pulte is the largest homebuilder in America.

This leadership is based on total sales volume including significant participation in master-planned communities throughout the US including the Summerlin and Green Valley Ranch communities of Las Vegas which are two of the premier master planned communities of the US. Pulte Homes also participates in specialized ventures under their Active Adult communities and custom home divisions.

The Pulte Home Corporation is very dedicated to their customers and the service that they provide them before and after they move into their home. Buyers participate in the entire building experience before construction begins and after they've moved into their home. With this customer interaction, Pulte Home is able to better address the sales, construction, mortgage and warranty service processes.

Pulte prides itself on being an industry leader in new and innovative ideas in construction technologies, materials and construction processes. Pulte Home Corporation's Southwest Building Unit (Las Vegas, Phoenix and Tucson) is committed to energy efficient construction practices and they are partnering with Energy Star, Building America, Engineered for Life and CSTRR in these endeavors. Pulte's Las Vegas Division was awarded first place in the 1998 Energy Value Housing Award contest for energy efficient housing by the NAHB.

The winning designs included Pulte's standard 2x6 exterior wall construction as well as innovative HVAC and conservation concepts that reduce heating/cooling energy consumption by 30-50 %. These concepts were introduced in the Las Vegas market under the Department of Energy's Build America Program. For these accomplishments, Pulte Homes has received national recognition. Under this Solar Hot Water initiative, renewable energy resources will now be added further reducing residential energy demands.

Nevada Power Co. (NPC), Pulte's partner in the design, construction and marketing phase of this program, is the largest utility in the State of Nevada with over 90% of the electrical power sales in the state. Under a pending merger agreement with Sierra Pacific Power Co. in northern Nevada, they will also have responsibility for marketing natural gas in northern Nevada.

Nevada Power Co. is dedicated to the solar alternative as a resource in the development of cleaner environment. They have recently initiated a "green power" program. Under their "Green Power" program, NPC has installed a 16 kW photovoltaic array and will, in 1999 install an additional 24 kW unit. This SWH Initiative will add to their "green power" program objectives. In recognition of their interest, NPC is cost sharing this Initiative and plans to be an active participant in the promotion of SWH in Las Vegas and Phoenix. In future years, NPC expects to expand this participation throughout their market region.

Project Objective

The objective of this Solar Water Heating Initiative is to introduce the solar water heating product into the residential, new-home market thereby increasing the awareness of the home builder, home buyer and the general public to the benefits of SHW. To meet this objective the Market/Business Plan is combining the resources of the partnership to promote the SWH benefits and educate the residential community. This will require the sale of the SWH product as a standard option with attractive retail pricing having proven performance and economics. Through these efforts the intent will be to continue to expand the acceptance and use of SHW in other communities and markets.

99/00 Sales Goals

The commitment of the project team is to design and install SWH systems in two Las Vegas subdivisions and one Phoenix subdivision. In these solar subdivisions, Pulte will offer solar water heating as an option and will sell and install an additional (20) SWH systems in owner occupied homes in Las Vegas with additional (10) SWH systems in Phoenix in 1999. Although this is the committed number of systems, Pulte's goal is to sell an additional (100) SHW systems in 1999 and (200) SHW systems in 2000 in their combined Las Vegas and Phoenix markets. Based on their experience with their energy efficient designs, Pulte anticipates the adoption of the SWH alternative by other builders in these communities which should further increase SWH market acceptance. Pulte has also expressed a willingness and interest in the promotion of the SWH product with other national and local builders

Five year Goals

After the SHW systems are introduced into the initial communities, Pulte will begin to expand them into other Pulte projects. Promotional materials, point of sale displays and product "mock ups" will be introduced into the sales offices of other Pulte projects currently in production or planned. Within 5 years, with confirmation of the SWH performance, Pulte conservatively estimates SWH sales of 5000 SWH systems with annual sales exceeding 2000 units per year.

Barriers

SWH, an emerging technology, represents a departure from traditional water heating technologies and requires the removal of barriers which could limit acceptance. The following is a list of objections that are being addressed to achieve the SHW project objectives.

A) Aesthetics

Numerous studies including DOE studies conducted by Focus Marketing Services and NAHB Research Center have documented negative perceptions in the construction industry and the general public towards SWH and have emphasized the importance of blending the design into the whole house to achieve buyer and community acceptance.

B) Economics

DOE studies and SWH industry experience have repeatedly identified the importance of return on investment by the homeowner, architect, and contractor. In the ROI analysis, retail system cost including product installation and operating and maintenance expenses must be recoverable within a reasonable period through energy savings. In this program, quantity purchases of proven, pre-packaged designs, installed as part of the new home construction process will provide an excellent opportunity provide the most economical SWH system.

C) Installation

The installation issues are the cost and quality of the installation and the long-term impact of the installation quality on performance, reliability, and durability. The solar industry experiences of the 70's and 80's provide ample evidence of the effect of shoddy installations on early system failures and/or excessive O&M expenses. Installation expenses can also substantially increase retail cost in the product if the product is introduced in an inappropriate situation. For this project installation quality is a serious issue and will be properly addressed.

D) Reliability

Potential issues include the manufactured product quality, materials durability, manufacturer's quality controls, and operational sensitivity to system maintenance.

E) Financing

Historically, SWH systems sold in new homes create several obstacles in the financing of the systems. First, lenders are usually not willing to provide full value for the system. This reduces the appraised value of the home and requires an increased down payment. Lenders also tend to treat the solar water heater cost in the base price of the home thereby impacting the loan qualification limits of the buyer.

F) Other Consumer Response Concerns

DOE studies have clearly identified the importance of overcoming buyer attitudes regarding solar water heating. In addition to the aesthetics, financing and economics issues listed above, the buyer is also concerned with the negative image created by earlier systems, the product maintenance, and the lack of brand names. All these consumer concerns will be resolved to produce a successful SWH program.

G) Building Codes & Community Restrictions

Solar firms in the 70's and 80's experienced considerable problems with unfavorable building codes and building official attitudes. The solution to these barriers was to sell and install without construction permits. Circumvention of the building codes is unacceptable with reputable builders and it will be necessary to install qualified designs using approved construction practices. This may require some modification of the local building codes and the instruction and training of local building officials.

Las Vegas and Phoenix have extensive master-planned communities with community specific CC&R's. Although state laws prohibit the exclusion of SWH, it will be important to work with the communities

to conform to community expectations and create a receptive environment for the SWH alternative.

Pricing

Pulte Home Corporation will sell the SWH as a standard appliance option using their proprietary pricing strategies. It is expected that the retail sales price will not exceed \$2000 per installed system. This price is expected to provide the homeowner with a return on their investment and allow the builder to receive a reasonable profit margin.

Systems & Their Selection

A rigorous system selection process was adopted for this program with consideration for the barriers listed above. Potential SRCC approved SWH systems were selected based on a preliminary screening of the SRCC candidate designs and their respective manufacturers using a set of selection criteria developed by the CSTRR team. Then, inspections of the product options were conducted at the manufacturer facilities. The leading candidates from this selection process are being subjected to an SRCC performance analysis in accordance with a CSTRR prepared Performance Analysis Plan to establish the performance and economics under typical user conditions. This analysis effort was considered a necessity to establish performance sensitivities to product installation variables and user hot water profiles. Several reliability and durability issues were identified during this selection process and it was determined that some pre-qualification testing was necessary to resolve these remaining reliability and durability issues. This testing has been documented in a SWH Test & Pre-Qualification Program Plan prepared by CSTRR with the assistance of the CSTRR team.

Based on this selection process and the product pricing, two system designs were selected for this program. The system design concepts are the integral collector storage (ICS) system and the indirect system. Three ICS manufacturers were reviewed. Sun Systems, Inc. product has been tentatively selected to supply the ICS system. Heliodyne was selected for the indirect system. Final model selections and manufacturers will be based on the results of the analysis program.

During the on-site inspections of the manufacturers facilities, a number of in-home installations were inspected. Based on these inspections and the building integration designs, it was concluded that any of the designs selected for review, when properly integrated into the roof structure, would not result in an aesthetic concern. Although the systems operate on different principles, they are both similar in cost and aesthetics. The collectors for the models under consideration will be either 3'x8' or 4'x 8' in size with thickness of approximately 8" for the ICS design and 4" for the indirect design. Both designs have an anodized aluminum frame with low iron glass glazings. At ground level, these units are expected to blend with the roofs and resemble skylights currently installed in most Pulte homes. Both designs will have minimal exposed piping and will not detract from the appearance.

Pulte/Manufacturer Business Agreements

Standard Pulte practices will be used to negotiate and purchase products for this program and all subsequent products purchases. All purchases will be made on the basis of standard Pulte purchase agreements. Pulte Homes, as a volume homebuilder, usually negotiates volume purchases based on committed product delivery schedules. Under this program, due to the uncertainties of consumer purchases, Pulte plans to make their initial purchases in (6) unit lots. When market data establishes buyer interest, purchase quantities and schedules will be established. The Pulte purchasing department is expected to negotiate larger purchases which could be used to reduce retail costs and further accelerate buyer acceptance.

Municipality/Community Approvals

As noted under the Barriers sections of this plan, building codes and building official acceptance of the product are critical to the success of SWH in the Pulte markets. This acceptance will require pre-planning and preparation of the documentation required by the Cities of Las Vegas and Phoenix. This documentation will include product design drawings and specifications, installation drawings, and the necessary permit applications. To streamline this process, Pulte plans to conduct briefings and training for the building departments in the communities.

The manufacturers have the product data required for SRCC certification. Pulte's in-house drafting department with the aid of the product manufacturers will prepare the necessary installation drawings, schematics and/or other technical information required by the building code review boards. It is crucial to have the blessing of the individual municipalities before starting the installation of these systems. To meet this need, Pulte will review community CC&R's as well as any master planned development's (such as Summerlin) design criteria to preclude violations of any restrictions on the placement of the solar collectors on the roofs of the homes. Whenever systems are installed in established communities, plans and designs for SWH heating will be coordinated with the community organizations prior to construction.

Installation/Installation Contractors

Pulte will purchase the product, but subcontract the system installation and maintenance in accordance with their standard construction practices. Pulte has selected their on-site plumbing/mechanical company for the installation. Under their subcontract agreement with the plumbing/mechanical contractor, the contractor will have responsibility for attaching the collector on the roof, making all plumbing connections, conducting final tests and inspections in accordance with manufacturer procedures and providing the product and installation warranty services.

Training

In partnership with the equipment manufacturers, Pulte will develop training programs for all aspects of the SHW product introduction. These training programs will address the product sales program, permit approval process, and product installation, inspection, and servicing as described below:

A) Sales/Marketing

The Pulte sales staff at the subdivisions being considered for the SWH product must be properly trained to not only sell the product, but to assess the buyer interests and lifestyle (hot water use profile). This interest and lifestyle will have to be matched to the SWH design and the availability of solar compatible lots and houses. Not all houses and

lots will be solar candidates. A house/lot combination without an accessible south-facing roof is unlikely to satisfy the required economic returns. Therefore, the buyer interested in a SWH system may have to select a more appropriate lot and/or house. Training sessions will be designed for the on-site sales.

Lifestyle will impact the SWH design selection and may even eliminate willing buyers. For example, a single person household is unlikely to utilize the full SWH resource under most operating conditions. Therefore, the ICS system design for this buyer would be uneconomical. Likewise a two-person family with a predominant morning hot water use is unlikely to fully utilize the benefits of an ICS system design which produces hot water during the daytime hours, but loses this heat during the nighttime hours. This two-person family may opt for an indirect design that can effectively store solar heated water.

These issues must be conveyed to the sales staff. A sales training program will be designed to assure the sales staff is able to effectively assess the buyer lifestyle and expectations. Based on the appropriate SWH product, the sales staff with the aid of performance and economic data will be able to provide the SWH buyer with accurate estimates of the solar advantage.

B) Installer/Pulte Inspection Staff

Industry experience and DOE studies have identified the product installation as a common failure cause. For this reason, a rigorous training program is planned for the installer and the on-site inspectors. This training will be developed with the aid of the equipment manufacturer using materials the manufacturer developed under the SRCC certification program. This training program will include a discussion of the solar water heating principles, installation guidelines, final inspection and checkout procedures and product service procedures.

C) Code compliance

A separate class will be provided for the local building inspectors to familiarize them with the solar water heater principles, design, installation, and inspection practices.

Warranties

In accordance with SRCC certification requirements, all manufacturers are required to provide 10-year warranties. Pulte supports this warranty policy and under Nevada State law provides guarantees a full one-year warranty of labor and material.

Pilot Program

Under the terms of the DOE Financial Assistance Contract, the CSTRR team will conduct a Pilot Program to include the design, construction, test and demonstration of 9 model homes involving three subdivisions – two in Las Vegas and one in Phoenix. The subdivisions will be priced for move-up and upper-end buyers. Each subdivision will have 3 solar heated models for test and demonstration purposes. Within each subdivision one home will have a solar water heater with gas auxiliary, a second model home will have a solar water heater with an electric auxiliary system and the third model home will be an all-electric home with solar water heating. The purpose of the electric auxiliary will be to compare the benefits of electric water heating with gas water heating. In a non-solar home, electrically heated water is more expensive than gas heated water. In the solar heated home, the electrical option may be the most economical option.

As noted in the preceding documentation, SWH designs are being selected and analyzed to assess expectations for system performance and economics. Each of these models will be instrumented and tested in accordance with the "SWH Test & Pre-Qualification Program Plan for the Las Vegas & Phoenix Markets". This model home testing will be conducted during each of the four seasons under controlled conditions using typical hot water use rates. Test results will confirm the system performance under simulated homeowner conditions with the results used to calculate solar fractions and annual

homeowner savings. Results will validate the performance/economic analysis and will be incorporated into the promotional materials.

Nevada Power Co. will be contributing design and marketing assistance for this project.

In addition to providing a test setup for system performance evaluation purposes, these models will also serve several other constructive purposes including:

- Training for the installers, inspection personnel, and building officials,
- Training for the sales and market staff,
- Assessment studies of buyer acceptance and reactions to the SWH option in Pulte Focus Group formats,
- Visual evidence of the SWH installation and the presentation performance and economic information.

Immediately after completing and testing the model homes, Pulte plans to introduce SWH as a buyer option at all their construction sites. At the solar model home sites, a minimum of six (6) buyers will be selected in each subdivision for an evaluation of the in-service performance of the SWH systems. These tests will be conducted as described in the test plan noted above. The results of these in-service tests will be used to provide additional confirmation of the SWH performance and the results will be included in the sales literature.

The Copper Sun, ICS, system will be installed at Pulte's Cypress Pointe community. The Heliodyne, indirect, system will be installed at Pulte's Crownridge community. The Phoenix subdivision has not been identified as of this date, but it will be in the upper-end buyer price category. All of the systems will be retrofitted into these homes to look and perform as if they were originally installed during the original construction.

Community Profiles

The Las Vegas communities in the Pilot Program were selected because of the energy efficient features that they both offer as well as the diverse buyer profiles that feedback studies require. A description of these subdivisions is provided.

Cypress Pointe

The Cypress Pointe community is located in the Summerlin village "The Arbors". These homes range from 1787 to 2260 sq. ft and start at \$173,000. They target the move up buyer profile. This community has been the for-runner for Pulte's Las Vegas division energy efficient housing program. These homes employ the "Cathedral Envelope" building technique in which the ceiling insulation is applied to the underside of the roof sheeting and in turn incorporates the attic and all of the HVAC components into the conditioned air space. Gas heated hot water, distributed via a fan-coil, and makes this the perfect choice for the SHW pilot program. Other advanced building techniques included at Cypress Pointe include 2x6 exterior walls; blown-in cellulose wall and ceiling insulation and vinyl framed low-e dual pane windows. This community is part of the Building America, Energy Star and Engineered for Life Programs. Cypress Pointe has established itself as the best selling community in its price range in Summerlin; the best selling master planned development in the country.

Crownridge

Crownridge is located in the Willows village of Summerlin. These homes range from 2422 to 3012 sq. ft and start at \$214,000. This product line is targeting the upper-end buyer. The Crownridge homes employ all of the same building techniques as Cypress Pointe except for the Hydronic heating.

Marketing

The objective of the marketing program will be to generate traffic to the communities offering SHW, enhance the acceptability of the systems and increase overall awareness of these programs to not only the Pulte customer, but the general public as well. The promotional programs to achieve these goals are as follows:

Point of sale displays/brochures

These "silent salesmen" will be placed in the sales areas of the models and distributed via mail. These promotional materials will be produced with the aid of the Pulte marketing experts and the product manufacturers. These "silent salesmen" will provide photos of the installed systems, technical data, easy to follow descriptions and explanations of the systems. Performance/economic test results will be added after the testing of the systems has been completed.

Nevada Power Promotion

Promotional materials called "stuffers" will be inserted into Nevada Power billing statements.

Radio ads

Radio spot ads as well as inserts in the live traffic reports or other local programs are being explored to identify the most beneficial outreach opportunity. Specific stations will be chosen based upon consumer research.

TV

TV advertising is an effective medium and inserts into the Weather Channel's local forecast segment or other popular shows will be selected.

Newspaper

The Las Vegas Review- Journal/Sun has a special Sunday addition dedicated to the local real estate market. One article regarding this solar program has already been inserted. As this program advances and informative materials are developed from the installations and testing, press releases should result in additional news articles. This Sunday edition will also be used to promote the solar option through periodic ads. These ads would be placed in addition to regular Pulte advertisements.

Special Event

Special events will be planned at each subdivision and these events have been discussed in the Outreach Program, which has been documented under separate cover. These Special Events are considered to be an important element in the introduction of SHW into Pulte programs.

Test Marketing

Homebuyers that have purchased the SHW systems will be surveyed. Focus groups and surveys will be performed at 30, 60, 90 and 120-day intervals after move in. Pulte will also perform exit interviews on perspective buyers touring the models to gain feedback on the initial impressions from the point of sales promotional materials.

Financing

Pulte Mortgage is an integral member in this initiative and has developed a special financing program to help promote interest in purchasing the SHW options. Pulte Mortgage will offer full value financing and a 1/8 % discount to the annual percentage rate of a fixed rate mortgage for buyers purchasing the system.

SWH Future

The future of the SHW option is already considered to be a success based on early buyer interest. Pulte expects this interest to grow after the introduction of the first systems and based on this interest Pulte will incorporate the SHW option into the standard option list of future projects being developed. One of the earliest growth opportunities will be the "Stallion Mountain" project in Las Vegas which will be a 760 lot project supporting three separate product lines in one community. This development will be the perfect candidate for the continuation of Pulte's energy efficient building program and SHW.

In the years to come, Pulte expects continued growth with projections for 17,000 homes in '99 and 18,000+ in 2000 and beyond. This project provides an ideal environment for support of SHW in the southwest. This region has expressed a growing concern and awareness for the need to build better, more environmentally friendly, homes. Pulte recognizes the importance of the energy conscious design and the contributions these types of programs can make to the environment and Pulte's success.

SCHEDULE

The schedule for the preceding activities has been documented in the attached SWH Project Plan. This schedule of events in the Project Plan identifies several key dates which impact this Marketing/Business Plan as follows:

- Selection of SWH design & manufacturer(s) Completed
- Preparation of pilot analysis & test plans Completed
- Marketing/Business Plan submittal Completed
- Design & install SWH systems
 - Las Vegas – (2) subdivisions 3/3/99
 - Phoenix – (1) subdivision 4/1/99
- Marketing program fully developed 4/30/99
- Begin SWH sales
 - Las Vegas
 - 1st sale 3/3/99
 - 20 systems 12/31/99
 - Phoenix
 - 1st sale 4/1/99
 - 10 systems 12/31/99

APPENDIX L

TEST PLAN

Pulte Home Solar Water Heating Systems

Tests Performed at the Center for Energy Research
College of Engineering
University of Nevada, Las Vegas

A. Test Objectives

The University of Nevada, College of Engineering, staff will conduct a test program of the SWH products being planned for the Las Vegas & Phoenix markets. The products to be tested will include an integral collector storage system (ICS) design manufactured by Sun Systems, Inc. and an indirect system design manufactured by Heliodyne, Inc. The primary objectives of the test program will be to:

- Evaluate seasonal thermal performance of the solar water heating (SWH) systems manufactured by Sun Systems, Inc. and Heliodyne, Inc in the Las Vegas market.
- Provide SWH systems performance data in a form that will be of value to the Pulte Homes marketing program.
- Examine the performance effects on the Sun Systems system based on typical homeowner water use profiles
- Investigate the effects of prolonged stagnation conditions on anti-freeze solutions in the Heliodyne system.
- Investigate the freeze resistance of Sun Systems, Inc. systems under typical Las Vegas winter conditions.

B. Installation and Test Procedures

The Sun Systems SWH products will be identical to those planned for sale by Pulte Homes and will be the newest configuration being offered by Sun Systems. In this latest design, eight 4" diameter copper tubes are packaged with the tubes in close proximity to each other such as to nearly fill the optical aperture thereby enhancing the optical efficiency and reducing thermal losses. In order to provide a nearly equivalent performance comparison of the Sun Systems system to the Heliodyne system, a 3' x 8' Heliodyne collector system will be tested. This differs from the 4' x 8' Heliodyne collector that will be installed and sold by Pulte Homes under this program. It will be necessary to extrapolate the 3' x 8'

Heliodyne collector test results for the when compiling performance data for the marketing effort.

The procedures for the test program are as follows:

1. Mount two Sun System (3x8) collectors and one Heliodyne (3x8) collectors on the south side of the roof of the Thomas Beam engineering B Building. The collectors will be mounted side by side, with no shading, and will face due south with a pitch equal to that provided by a 5:12 roof. This is the pitch typically used by Pulte Homes in their Las Vegas construction projects.
2. Connect electric water heaters to each of the three SWH systems. These electric water heaters will be located in close proximity to their respective collectors and will be protected from direct exposure to the weather to reduce solar gain and to minimize heat loss during the winter conditions. See attached diagrams.
3. Connect 208-v single-phase power and a watt-hour meter to the upper heating element in each of the water heaters. The lower heating element will not be used. The pumps in the Heliodyne system will be connected to a 110v power source and the power draw of these pumps will be measured with a watt-hour meter that is separate from the heating element watt-hour meter.
4. Connect the campus water supply to each of the collector/water heater systems. The water supply will have a flow controller that can furnish the desired time-of-day variation of water flow to each system. See attached water draw profiles. One of the Sun Systems, Inc. systems and the Heliodyne system will be furnished with the SRCC water draw schedule. The second Sun Systems system will be furnished with a water draw that emphasizes morning usage. Depending on the availability of funds, automated water flow meters will be used such that flow can be controlled based on water flow rate feedback measurements. Water exiting the heaters will be discharged into a floor drain. All water lines that can potentially freeze will be outfitted with electrical heating tapes and rheostat controllers.
5. Thermocouples will be installed to measure temperatures in a number of system locations. See attached diagrams. Measurements will include: 1) the water supply to each system (the water heater input for the Heliodyne system and the collector input for the Sun Systems, Inc. systems), 2) fluid from the collectors, 3) fluid from the water heater, and 4) outdoor ambient in a sun-protected location near the collectors.

Thermocouples will be mounted inside each of the collectors. On the Heliodyne collector, the absorber temperature will be monitored. This measurement will be important during stagnation testing. The internal manifolds and the 4" absorber tubes on the Sun Systems collector will be monitored for evaluation of maximum temperatures during stagnation testing and for monitoring possible freeze conditions during the winter months.

6. Wind (speed and direction) and solar radiation (total insolation in the plane of the collector) will be monitored as available, but measurements of these parameters are not viewed as primary data involved in the test plan.
7. The systems will be filled with appropriate fluids – campus water for the Sun Systems system and an antifreeze solution for the Heliodyne system. As specified by Heliodyne, the antifreeze solution will be 50% Dowtherm HD and 50% distilled water.
8. The desired water draw schedule will be programmed and calibrated for each collector. See attached schedules.
9. All three water heaters will be controlled at 125 °F.
10. All data will be recorded and analyzed using a personal computer with LabVIEW software and hardware used for system control and data collection

C. Performance Testing

Operation of the systems will commence two days prior to the start of the test program without formally recording data. This will permit the systems to reach a steady state condition. After this stabilizing period, the formal data collection will be initiated.

The following data will be taken at ten-minute intervals during daytime hours and every hour during nighttime intervals. Data recordings will be taken in an appropriate manner to permit computerized analysis.

1. Temperature readings at each of the locations noted above.
2. Watt-hour meter output readings.
3. Total insolation in the plane of the collectors and wind speed and direction.

This data will be taken for at least a 30-day period during each of the four seasons. Sufficient data will be taken to permit computation of the annual energy savings based on electrical consumption of the solar water heating systems.

During a summer month when performance testing is not taking place, both SWH designs will be tested under stagnation conditions. For the Sun Systems, Inc. systems, this will require the elimination of water draws. For the Heliodyne system, collector pump power will be disabled, as this will cause this system to stagnate. The stagnation test of greatest interest will be the Heliodyne system, as this test will permit an assessment of possible changes to the antifreeze solution. Throughout this one-month period the absorber panel temperatures will be monitored on all systems on an hourly basis. For the Heliodyne system, PH levels will be monitored, as this measurement will serve as an indicator of possible degradation in the antifreeze solutions.

Throughout the winter months, Sun System collectors will be monitored to assess possible freezing under extreme winter conditions. Heating tape will be used to protect the collector if freezing temperatures are recorded.

D. Data Presentation

The data taken during these tests will be used to provide the following information:

1. Measurements of auxiliary energy usage and estimates of total annual energy required maintaining the desired temperature set points. These measurements will be compared to water heater energy requirements without the SWH contributions. Energy use will be overlaid on the water draw schedule and shown as a function of time. This type of data will be provided for all three systems.
2. Based on the measurements in item 1 typical annual electrical energy savings for Pulte Home homeowners will be computed.
3. Plots of temperature-time variations will be provided. Temperatures of particular interest are the ambient temperature, the water supply temperature, and the temperature of the water leaving each of the three heaters.
4. PH measurements of the antifreeze solution in the Heliodyne systems.
5. Any freezing conditions encountered on the Sun Systems collector/storage will be noted along with indications of the climatic conditions when these occurred.

E. Anticipated Problems and Their Treatment

Of concern is the fact that all of the components will be located outside on the roof of the engineering building. This exposure has the potential for influencing the test results and these effects will be mitigated to the maximum extent possible. One concern is the effects of ambient temperature extremes that will be imposed on the piping and water heaters.

A significant length of water supply line will be present across the roof of the building. This could bias the inlet water temperature toward the ambient temperature more so than might be found in a typical residential application. This will be treated in two ways. First, the supply lines will be insulated. Second, if significant differences from typical city water supply temperatures are still present, the data will be presented in two ways. One is the basic uncorrected form as measured. The other will be a correction of heating demand based on the differential between the measured supply temperature to the SWH systems and the water main supply temperatures as provided by the Las Vegas Valley Water District.

This outdoor ambient temperature will also influence the water heaters although they will be somewhat protected under the collectors. Despite these protective precautions, the open

environment on top of the building will have an impact. To mitigate these effects, the water heaters will be insulated.

Flow control and measurement and cost control are the most challenging element of the test program. Costs for the flow control system are still being determined and loaner possibilities are being explored. Four options are being considered and are presented below. These are listed below from the most desirable and (most expensive) to the least desirable (and least expensive):

- Option 1 Three electronically controlled valves to be used with one valve dedicated to each system. Feedback measurements to be used to control the flow on each system. Flow to be calibrated when each new phase of testing begins.
- Option 2 Two electronically controlled valves to be used with one valve used to control equal flow rates to the Sun Systems system and the Heliodyne system using the SRCC flow profile. As with Option 1, flow would be controlled using feedback from flow measurements. The second flow meter would be used to control flow to the second Sun Systems system having a morning water draw profile. Both flow meters would be calibrated when each new phase of testing begins.
- Option 3 Three electronically controlled valves would be used without feedback. One valve would be dedicated to each of the three systems. Flow rates would be pre-calibrated and periodically re-calibrated.
- Option 4 Two electronically controlled valves to be used without feedback with one valve used to control equal flow rates to the Sun Systems system and the Heliodyne system using the SRCC flow profile. As with Option 3, flow would be controlled based on pre-calibrated flow measurements. The second flow meter would be used to control flow to the second Sun Systems system having a morning water draw profile. Both flow meters would be calibrated at the start of each test phase.

System instrumentation diagrams for each system and draw schedules for the SRCC and CSTRR water use profiles are provided below:

SUN SYSTEMS TEST ARRANGEMENT

Key

Watt-hour meter

Electronically operated valve

Thermocouple location

Active heater element

Inactive heater element

SRCC Dual Peak Draw Profile

<u>Hour</u>	<u>Draw (min.)</u>	<u>Gal/hr.</u>
1	5	0.95970
2	0	0.00000
3	0	0.00000
4	0	0.00000
5	0	0.00000
6	1.5	0.95970
7	30	5.75820
8	35	6.71790
9	30	5.75820
10	20	3.83880
11	20	3.83880
12	15	2.87910
13	15	2.87910
14	10	1.91940
15	5	0.95970
16	10	1.91940
17	15	2.87910
18	15	2.87910
19	20	3.83880
20	25	4.79850
21	20	3.83880
22	15	2.87910
23	15	2.87910
24	10	1.91940

Total gallons per day = 64.29990

CSTRR Morning Peak Draw Profile

Hour	Draw (min.)	Gal/hr.
1	0	0.00000
2	0	0.00000
3	0	0.00000
4	0	0.00000
5	0	0.00000
6	5	2.14335
7	25	10.71675
8	60	25.72020
9	10	4.28670
10	5	2.14335
11	5	2.14335
12	5	2.14335
13	0	0.00000
14	0	0.00000
15	0	0.00000
16	5	2.14335
17	15	6.43005
18	5	2.14335
19	5	2.14335
20	0	0.00000
21	5	2.14335
22	0	0.00000
23	0	0.00000
24	0	0.00000

Total gallons per day = 64.30050

APPENDIX M

Technical Manual for the TBE Solar Collector Monitoring System

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Mechanical Engineering Department**

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Chapter 1

Introduction

The Solar Collector Monitoring Program is designed with the main objective of assisting in the evaluation of typical seasonal thermal performance in the Las Vegas area for representative solar domestic water heating systems. In particular, three solar collectors are being evaluated, two Sun System (3'x8') collectors and one Heliodyne (3'x8') collector.

The solar collector monitoring system integrates plumbing, electrical, and temperature measurement systems. Each of these three systems can be described separately, but are collectively dependent on one another for the proper performance of the overall system. Each of the collector systems are tested in identical environmental conditions side by side one another and are constructed in a manner similar to that which could be found in a residential dwelling incorporating solar collector technology. Additionally, a standard water heater setup not using solar collectors is used as a control against which the collectors' performances can be evaluated. Appropriate inlet and outlet temperatures are monitored on each system in addition power and water usage. Each system employs a feedback control system to regulate the water flow in a profile typical of daily residential household usage. A data collection and feedback control system are regulated by a single centrally located Pentium personal computer with a specialized hardware and software interface.

This manual includes both general system descriptions and detailed component layouts for the collector systems. In addition to the physical details of the systems, the hardware and software components of the computer interface with these components are discussed in detail. This manual is designed to be comprehensive of all components that make up the "unified" collector system and includes sections on data analysis, system initialization and system maintenance.

Chapter 2

General System Description

PHYSICAL LAYOUT

A general description of the construction criteria follows.

- Two Sun System (3'x8') and one Heliodyne (3'x8') collectors are mounted on the south side of the roof of Thomas Beam Engineering B Building. The collectors are mounted side by side, with no shading. They are facing due south with a pitch equal to that provided by a 5:12 roof, typical of that which is used by Pulte Homes in the construction of their housing developments.
- Three electric water heaters are installed in close proximity under the collectors, with pipe connections between each of the heaters and its companion solar collector.
- Each water heater is connected to 208V single-phase power with a watt-hour meter connected to the upper heating element to each respective heater. The lower heating element in each heater is not used.
- The circulating pumps necessary for the operation of the Heliodyne System are connected to appropriate power supplies with a watt-hour meter connected to measure the power used by the pumps.
- The campus water supply is connected to each of the collector/water heater systems. The water supply has a flow controller that can furnish the desired time-of-day variation of water flow to each system. One each of the Sun Systems and the Heliodyne will be furnished with SRCC water draw schedule, and one of the Sun Systems units will be furnished with a water draw that emphasizes morning usage (CSTRR schedule). The water exiting from the heaters is routed to a drain.
- All lines that can potentially freeze are outfitted with electrical heating tapes.
- Thermocouples are installed at several key locations along each of the systems.
- The systems are filled with water provided by the campus water supply. The Heliodyne system an anti-freeze/water mixture is maintained within the collector loop. The anti-freeze solution is 50% Dowtherm HD with 50% distilled water.
- The desired water draw schedule is programmed and for each collector. This schedule is maintained through a feedback control loop on each system through the real time monitoring of a digital flow meter.
- All four water heaters are maintained at the desired set-point temperature of $125^{\circ}\text{F} \pm 1^{\circ}\text{F}$.
- A Pentium 450 PC outfitted with LabVIEW software and hardware is used for systems' control and data polling.

THE FOUR COLLECTION SYSTEMS

As noted above, four separate collection systems are being monitored. These four systems consist of three configurations, the Sun System configuration, the Heliodyne system configuration, and the Control Heater configuration. Two of the four systems have the Sun System configuration with the difference being the flow schedules that they are subjected to.

Each system can be broken down into three major components: the plumbing system, the electrical system, and the temperature measurement system. The plumbing systems for each of the collection systems is similar in nature and function, but vary considerably from one another in actual layout. The electrical systems for each collection system are nearly identical, as are the key temperatures that are measured throughout each system.

The Control Heater System

The control heater system is very similar to a setup that would be found in a typical residential household. The SRCC flow schedule designates the flow rate of water through this system. The water flowing through the system is subjected to the water pressure from the campus water supply. As the flow rate through the system varies throughout the day, the water is heated by an electric water heater and exits it at a preset temperature. A wattmeter is connected to the water heater to measure its power usage.

In addition to recording power usage, the temperature of the water entering and exiting the heater are measured as well as the cumulative flow and actual flow rates of the water throughout the day. This information is stored on a central computer and is used as a control against which the Sun and Heliodyne systems' performances will be measured.

The Two Sun Systems

The Sun Systems are similar to the control heater system layout except that the cold water supply is preheated through the Sun System Solar Collectors *before* entering the water heater. The solar collectors are mounted at a 5:12 pitch facing due south so as to have access to direct sunlight throughout the day. A particular flow schedule (either the SRCC or CSTRR schedule depending on the system) is introduced to each collector system. The water flowing through the system is subjected to the water pressure from the campus water supply. As the flow rate through each system varies throughout the day, the water is first preheated by flowing through the Sun System Collectors and finally heated by an electric water heater to exit at a preset temperature. A wattmeter is connected to the water heater to measure its power usage.

In addition recording power usage, the temperature of the water entering and exiting both the heater and solar collector are measured. The cumulative and actual flow rate of the water passing through each system are also measured and recorded.

The Heliodyne System

The Heliodyne collection system is similar to the control heater system layout with the exception that the Heliodyne collector works in conjunction with the electric water heater to heat the water *after* it has already entered the water heater. In this system, water in the lower portion of the water heater is circulated through a heat exchanger where it is warmed by a counter circulating and warmer antifreeze solution. The antifreeze is circulated through a separate closed loop system where it is heated in a Heliodyne System solar collector. Like the Sun Systems, this collector is mounted at a 5:12 pitch facing due south so as to have access to direct sunlight throughout the day.

A special thermocouple mounted at the exit side of the solar collector measures the outlet temperature of the antifreeze and compares it with the temperature of the water circulating through the heat exchanger. The circulating pumps are proportionally controlled by this temperature comparison so that when the water in the tank becomes warmer than the antifreeze circulating through the collector, the circulating pumps shut off.

The SRCC flow schedule designates the flow rate of water through this system. The water flowing through the system is subjected to the water pressure from the campus water supply. As the flow rate through the system varies throughout the day, it is heated by the electric water heater and the Heliodyne Solar Collector and exits it at a preset temperature. A wattmeter is connected to the water heater to measure its power usage.

In addition recording power usage, the temperature of the water entering and exiting both the heater and the temperature of the antifreeze entering and exiting the solar collector are measured. The cumulative and actual flow rate of the water passing through each system are also measured and recorded.

This collector system has the advantage of withstanding freezing temperature that can damage solar collectors that rely on water as their medium for heat transfer. The main disadvantage is that the antifreeze solution may rise in pH which can potentially rust out the system. Details regarding this may be found in *Chapter 12: Maintenance*.

Chapter 3

Plumbing System

GENERAL CONSTRUCTION

The plumbing system is used to pipe water to the various collector systems where it will be circulated through the solar collectors and water heaters and finally to a drain where it will be discarded. It is also used to circulate an antifreeze solution through the Heliodyne solar collector where heat collected by the antifreeze is transferred via a heat exchanger to a portion of the water supplied to the Heliodyne system. A schematic describing the flow path of the water and antifreeze through the systems can be referenced to at the end of this chapter.

The pipe size used throughout the system is 3/4" copper tubing with the appropriate fittings used to integrate the various necessary components into it. This tubing is insulated throughout to minimize heat loss and heat gradients throughout each system. Additionally, a fiberglass-insulating blanket is wrapped around each heater to improve their efficiencies and to reduce the effect of outdoor temperature exposure to them. The objective of the insulation is to reduce the effects that ambient temperatures may have on each system while better simulating a household solar collection system where the heater and piping are more likely to be in a temperature regulated environment.

SUN SYSTEMS LAYOUT

Collector systems #1 and #4 employ the Sun System solar collector. The collectors operate with water as their heat storage medium. As the Plumbing Diagram shows, cold water enters the system through the lower inlet of the solar collector. This water collects solar energy in the form of heat until it exits the top of the collector and is piped into the "cold water" inlet of the electric water heater. As necessary, water is piped out of the "hot water" outlet of the water heater passing by the upper heating element. This heating element ensures that the appropriate exit temperature of $125^{\circ}\text{F} \pm 1^{\circ}\text{F}$ is maintained.

An Electronic Proportional Flow Control Valve and a Digital Flow Meter working in a feedback control loop regulate the flow of water through the Sun System. Notably, the valve and meter are located on the drain side of the system. This location ensures that the entire system remains hydraulically pressurized by the supply line pressure.

These systems also incorporate a mixing valve and a bypass valve. The mixing valve allows the temperature of the water entering the drainpipe to be cooled by the supply line. In typical operation, this valve is to remain closed so that the exit temperature of the water heater is not adversely affected by cold water contamination. The bypass valve allows the collector to be closed off from the heater so that the collector is bypassed. In the case where the bypass valve is used, the supply line routes directly into the "cold water" inlet of the electric water heater. In typical operation, the bypass valve is to remain open.

Other features of the Sun System include several strategically placed outlet valves that may be used for bleeding the system or to check for line pressure. Shut off valves at either end of the system may be used to close an individual system off from the other systems and may be used to assist in system calibration. A check valve on the supply and drain lines of each system eliminates the possibility of back-flow contamination to the other systems.

Additionally, an analog temperature gauge is incorporated into the outlet line of the solar collector as an easy reference to the respective outlet temperatures.

HELIODYNE SYSTEM LAYOUT

Collector system #2 employs the Heliodyne solar collector. This collector operates with an anti-freeze solution of 50% Dowtherm HD with 50% distilled water as its heat transfer medium. As the Plumbing Diagram shows, cold water enters the system through the "cold water" inlet of the electric water heater. This water is initially heated through a heat exchanger by heat collected from the solar collector. As necessary, water is piped out of the "hot water" outlet of the water heater passing by the upper heating element. This heating element ensures that the appropriate exit temperature of $125^{\circ}\text{F} \pm 1^{\circ}\text{F}$ is maintained.

The heat exchanger operates by exchanging heat energy from the anti-freeze solution circulated through the collector to colder water circulated from the water heater. The heat exchanger operates only when the water exiting the collector is warmer than the water circulating through the water heater. A thermocouple mounted near the exit of the solar collector monitors the exit temperature of the collector and is used to activate the circulating pumps for the water and anti-freeze.

An Electronic Proportional Flow Control Valve and a Digital Flow Meter working in a feedback control loop regulate the flow of water through the Heliodyne system. Notably, the valve and meter are located on the drain side of the system. This location ensures that the entire system remains hydraulically pressurized by the supply line pressure.

Other features of the Heliodyne system include several strategically placed outlet valves that may be used for bleeding the system or to check for line pressure. Shut off valves at either end of the system may be used to close the system off from the other systems and may be used to assist in system calibration. A check valve on the supply and drain lines of the system eliminates the possibility of back-flow contamination to the other systems.

Additionally, a pressure gauge is mounted to line circulating the antifreeze solution in conjunction with an expansion tank. These are used to monitor and regulate the pressure inside the antifreeze loop. This pressure is typically kept between 15-30 psi.

CONTROL HEATER LAYOUT

System #3 acts as a control to monitor against the Sun and Heliodyne Systems. As the Plumbing Diagram shows, this heater system is set up similar to that which would be found in a residential dwelling. Cold water enters the system through the "cold water" inlet of the electric water heater. As necessary, water is piped out of the "hot water" outlet of the water heater passing by the upper heating element. This heating element ensures that the appropriate exit temperature of $125^{\circ}\text{F} \pm 1^{\circ}\text{F}$ is maintained. No solar collector is utilized in this setup.

An Electronic Proportional Flow Control Valve and a Digital Flow Meter working in a feedback control loop regulate the flow of water through the heater system. Notably, the valve and meter are located on the drain side of the system. This location ensures that the entire system remains hydraulically pressurized by the supply line pressure.

Other features of the heater system include several strategically placed outlet valves that may be used for bleeding the system or to check for line pressure. Shut off valves at either end of the system may be used to close an individual system off from the other systems and may be used to assist in system calibration. A check valve on the supply and drain lines of the system eliminates the possibility of back-flow contamination to the other systems.

FLOW CONTROL SCHEDULES

Each of the collector systems is subjected to a water draw that is representative of a typical residential household. Two separate draw profiles are used; one of which accentuates morning water usage.

Although the profiles slightly differ from one another, the total flow through each system provided by these profiles is identical - 64.2999 gallons. The flow rates are designed to be changed every hour on the hour. For example, the first hour of the day takes place between midnight and 1:00 am where the SRCC profile dictates a flow of ~1 gal/hr and the CSTRR profile has a flow rate of 0.00 gal/hr.

The flow rate of water throughout each system is 11.5164 gallons/hour regardless of the hourly draw for a given time period. As such, the water draw for each system ranges between 0 minutes for no flow up to 35 minutes for high hourly flow rates. For example, the 11:00 AM flow schedule requires an hourly flow rate of 2.8791 gallons per hour. At a flow rate of 11.5164 gallons per hour, the total draw requirements will be completed in exactly 15 minutes. For this case, a control valve would open up at precisely 11:00 AM to allow a flow into the given system and close at precisely 11:15 AM. It would not open again until 12:00 noon where the next draw would be implemented.

The *Water Draw Profiles for TBE Collector Systems* diagram at the chapter's end provides a detailed overview of the SRCC and SCTR R draw profiles.

SRCC DUAL PEAK DRAW PROFILE

This draw profile is used on three of the collector systems - one of the Sun Systems, the Heliodyne System, and the Control System. This draw profile consists of two peaks that represent high water usage in the morning and evening hours with little or no water draw at midday or late into the evening.

CSTRR MORNING PEAK DRAW PROFILE

This draw profile is used on one of the Sun Systems as a comparison to the SRCC draw profile. This draw profile emphasizes a morning peak usage of hot water in a household. The entirety of this peak is completed before 7:00 am where after the profile is identical to the SRCC profile.

SOLAR COLLECTOR SYSTEM PLUMBING DIAGRAM

Antifreeze		Thermocouple # & Placement		Heat Exchanger		Water Heater		Shut Off Valve
Hot Water		FP-5061 Pulse Flow Meter		Solar Collector		Expansion Tank		Bypass Valve
Cold Water		Temperature/Pressure Gauge		PID Flow Control Valve		Outlet Valve		Mixing Valve
		Check Valve						Pump

Chapter 4

Electrical System

ELECTRICAL SYSTEM OVERVIEW

The basic electrical layout for all four solar systems is identical. The electrical system consists of several individual components which, when integrated together, forms a pseudo-intelligent system that monitors, controls, and records the dynamic parameters of each system. The *Signal Flow Diagram* at the end of this chapter aids in the description and understanding of the electrical portion of the solar collection systems. Specific details regarding the individual components can be found in the following section - *Description of System Components*.

The central component of the electrical system is a Pentium 450 personal computer. The computer houses the hardware and software that interfaces and controls the external components of the system. Three separate hardware devices from National Instruments are installed within the computer system - two that are general DAQ cards and the other specifically for measuring high precision temperatures and voltages. Combined, the two general DAQ cards have four (4) counter timer chips to measure the pulse signals from four separate flow sensors, four (4) analog output channels for to provide a control signal to four electronically controlled flow valves, five (5) analog input channels to read the pulse input from five watt meters that monitor the power usage from the four collector systems, and several +5 VDC ports to power the four flow sensors. The computer also houses the LabVIEW programming language and the VirtualBench Logger software package. A program (otherwise known as a VI or Virtual Instrument) is run under the LabVIEW environment that controls the operations of the DAQ cards. This program is called *Apollo.vi*. The VirtualBench Logger software provides control over a third high precision DAQ card that is used for measuring temperatures.

The two general-purpose DAQ cards (the PCI-6024E and the PCI-6040E series cards) are connected via SH6868 cables to CB-68LP connector blocks. These connector blocks provide an interface between the DAQ cards and the systems components via screw terminals on the block. Additionally, the NI-4351 DAQ card is interfaced through a specialized TBX-68T connector block via a SH6868 connector cable.

FEEDBACK CONTROL OF FLOW

The signal flow path to each of the four collector systems is identical. Three components are involved in the control mechanism for each system. The heart of the control systems is a flow sensor that measures the flow of water and an electronic control valve that regulates this flow. Initially, the flow sensor (which is powered by a 5 VDC line from a DAQ card) sends a signal to the computer with information regarding the flow rate of water through its system. The computer compares this information to a predefined flow schedule for that system and returns a 0-5 VDC signal out to the electronic control valve to regulate or maintain the flow of water through the system. This signal is converted by a signal conditioner to a 4-20 mA signal that is the signal actually read by the control valve. This process is repeated at a frequency of about 1 Hz to maintain a fine control over the flow rate of water through each system. The control valves are powered by a separate 12 VDC power source while the signal conditioners are powered by a separate 5 VDC power source.

MEASURING TEMPERATURES

The VirtualBench Logger, in combination with the NI-4351 DAQ card, measures 14 key temperatures throughout all four systems. These thermocouples are connected to 14 separate channels that are accessed through the connector block. Details covering this system are given in *Chapter 5: Temperature Monitoring System*.

DESCRIPTION OF SYSTEM COMPONENTS

FP-5061 Micro-Flow Sensor

The FP-5061 Micro-Flow Sensor, distributed by Omega Engineering (www.omega.com), is a low-flow fluid measurement sensor. As water flows through the sensor, a pulse signal is generated which can be measured to determine both the cumulative flow and flow-rate of the fluid passing through it.

The Micro-Flow Sensor has a three-wire tail with a black, a red, and a ground wire. The black wire must be connected to a 5-24 VDC source to provide power to the meter. For the solar system, this source is a +5 volt terminal on one of two NI E-series DAQ cards. The red wire carries the output pulse signal from the flow sensor. This signal is in the form of a square pulse wave that is proportional in amplitude to the input voltage signal. This wire must be connected to a Source Counter Timer input on a NI E-series DAQ card in order to be read. The counter timer chips incorporated within the DAQ cards have the ability to count pulse signals at very high rates. The ground wire is simply connected to a digital ground (DGND) port on the DAQ card on which the red wire was connected.

Two heater system incorporates a micro-flow sensor on the drain side of the plumbing system just before the flow control valve. More detailed specifications regarding this component can be found in the appendix.

Sea-Metrics SPX 3/8" Low Flow Meter

The SPX Low flow meter, distributed by Sea-Metrics (www.seametrics.com), is a low-flow fluid measurement sensor. This sensor was introduced as a more rugged and reliable replacement to the FP-5061 Micro-Flow Sensors. As water flows through the sensor, a pulse signal is generated which can be measured to determine both the cumulative flow and flow-rate of the fluid passing through it.

The Micro-Flow Sensor has a three-wire tail with a black, a red, and a white wire. The red wire must be connected to a 6-24 VDC source to provide power to the meter. For the solar system, this source is a separate +6 VDC power supply. The white wire carries the output pulse signal from the flow sensor. This signal is in the form of a square pulse wave that is proportional in amplitude to the input voltage signal. This wire must be connected to a Source Counter Timer input on a NI E-series DAQ card in order to be read. The counter timer chips incorporated within the DAQ cards have the ability to count pulse signals at very high rates. The black wire is simply connected to the minus(-) terminal on the power supply.

Two heater system incorporates a micro-flow sensor on the drain side of the plumbing system just before the flow control valve. More detailed specifications regarding this component can be found in the appendix.

Hass Engineering Proportional Control Valves

The ECV-500B Electronic Control Valve and the EPV-312B Electronic Proportional Valve, both manufactured and distributed by Hass Engineering (www.hassmfg.com), are electronic valves that open and close under the command of a 1-5Vdc or 4-20mA input signal. These valves are used to regulate the flow of water through each heater system using a predefined flow schedule.

The ECV-500B has a watertight casing surrounding a step motor and controller card. This unit is larger and has more options than the EPV-312B but functions identically to the EPV-312B with the limited use of its options. The ECV-500B has a seven-wire tail with only four of these being utilized. These are further detailed under the EPV-312B description. The ECV-500B's flow through requires 3/4" NPT fittings and is utilized on two of the solar collector systems to control the flow rate of water through them. Specifically, they are used on the Heliodyne and Control Heater systems.

The EPV-312B is a smaller unit with fewer but identical functions to the ECV-500B. This unit has a four-wire tail with each wire being utilized in the control action of the valve. The white lead is attached to a +4-20mA terminal on a 5B39-01 Analog Device signal conditioner while the black lead is connected to a -4-20mA terminal. The red lead supplies +12-24VDC to the valve while the red/white lead acts as a Common. These are both attached to a separate 12VDC power supply. The EPV-312B's flow through requires 1/2" NPT fittings and is utilized on both Sun Systems to control the flow rate of water through them. The smaller fitting size allows for a finer degree of flow control over the ECV-500B. Both valve types, however, allow a high degree of control over the flow rate through the systems. The 4-20mA control signal option is chosen over the 1-5 V control signal option because signal loss through the line is significantly reduced.

Each heater system incorporates a proportional flow control valve on the tail end of the drain side of the plumbing system. They are located downstream of the FP-5061 Micro-Flow Sensors. More detailed specifications regarding this component can be found in the appendix.

Analog Devices 5B39-01 0-5 Volt → 4-20 mA Signal Conditioner

The 5B39-01 0-5 Volt → 4-20 mA Signal Conditioner is manufactured by Analog Devices (www.analogdevices.com) and is responsible for converting a voltage signal produce by a National Instruments DAQ card into a mA signal that can be understood by the Electronic Valves. This mA signal regulates the position of the valve from totally closed (4 mA) to wide open (20 mA).

This device is mounted on a special board on which five screw terminals are located by which the device can be accessed. These terminals provide a 4-20+ mA output, a 4-20- mA output, a common, a 0-5 VDC signal voltage input, a 0-5+ VDC power input, and a 0-5- VDC power input. A diagram outlining the circuit design of the mounting board can be found at the chapter's end.

More detailed specifications regarding this component can be found in the appendix.

National Instruments PCI-MIO-16E-4 DAQ Card (6040E Series)

The PCI-MIO-16E-4 Data Acquisition Card, manufactured and distributed by National Instruments (www.ni.com) provides one of two interfaces between the physical components of the heater systems and the LabVIEW program that controls, analyzes, stores, and outputs signals to and from these physical components. This DAQ card is installed in a PCI slot of a centrally located Pentium computer system in which the LabVIEW programming language and control VI are installed. The key useful features of the MIO-16E-4 DAQ card are:

- Two (2) source counter timers which are used to measure the pulse signal from two FP-5061 Micro-Flow Sensors. The digital ground ports are used as a common to the timer chips.
- Two (2) analog output channels which are used to control the motion of the Electronic Proportional Valves. The voltage signals generated from these channels are transformed through the Analog Devices 5B39-01 signal conditioner to a mA signal necessary for valve control. The analog ground ports are used as a common for the output voltage signal.
- Five (5) of eight differential analog input channels used to monitor the pulse signal generated from the Watt meters used to measure the power consumption of the heater systems.
- The 5-volt excitation port used as a power source to the two measured Micro-Flow Sensors.

The sampling rate for a 6040 series card is 500 kS/s for single channel scanning and 250 kS/s for multi-channel scanning. The streaming-to-disk rate is up to 250 kS/s. More detailed specifications regarding this component can be found in the appendix or by referencing the *PCI E Series Users Manual*. The CB-68LP Connector Block is necessary as a card into which the various instruments can be electrically connected by screw terminals to the PCI-MIO-16E-4.

National Instruments PCI-6024E DAQ Card

The PCI-6024E Data Acquisition Card, manufactured and distributed by National Instruments (www.ni.com) provides one of two interfaces between the physical components of the heater systems and the LabVIEW program that controls, analyzes, stores, and outputs signals to and from these physical components. This DAQ card is installed in a PCI slot of a centrally located Pentium computer system in which the LabVIEW programming language and control VI are installed. The key useful features of the 6024E card are:

- Two (2) source counter timers which are used to measure the pulse signal from two FP-5061 Micro-Flow Sensors. The digital ground ports are used as a common to the timer chips.
- Two (2) analog output channels which are used to control the motion of the Electronic Proportional Valves. The voltage signals generated from these channels are transformed through the Analog Devices 5B39-01 signal conditioner to a mA signal necessary for valve control. The analog ground ports are used as a common for the output voltage signal.
- The 5-volt excitation port used as a power source to the two measured Micro-Flow Sensors.

The sampling rate for a 6024E series card is 200 kS/s for single channel scanning and 250 kS/s for multi-channel scanning. The streaming-to-disk rate is up to 200 kS/s. More detailed specifications regarding this component can be found in the appendix or by referencing the *PCI-6024E Users Manual*. The CB-68LP Connector Block is necessary as a card into which the various instruments can be electrically connected by screw terminals to the PCI-6024E.

National Instruments TBX-68T Connector Block

The TBX-68T connector block, manufactured and distributed by National Instruments (www.ni.com) is a non-shielded 16 channel screw terminal block into which up to 14 separate thermocouples can be connected. A sensor for cold-junction compensation on channel 0 and autozeroing circuitry on channel 1 are reserved on the block allowing for only 14 additional measurement channels. A plastic cover over the block minimizes temperature gradients across the block. This block is connected to the NI-4351 High Precision Temperature Logging card via a SH6868 Shielded Cable. More detailed specifications regarding this component can be found in the appendix.

National Instruments SH6868 Shielded Cable

The SH6868 Shielded Cable, manufactured and distributed by National Instruments (www.ni.com) provides a connection between the 6040E and 6024E series DAQ cards and their respective connector blocks. More detailed specifications regarding this component can be found in the appendix.

Electrical Signal Flow Diagram

SOLAR COLLECTOR SYSTEM WIRING DIAGRAM

Chapter 5

Temperature Monitoring System

MEASUREMENT PARAMETERS

Temperature measurements, in conjunction with the flow rate of water through the collection systems, serve to indicate the amount of energy the system has gained or lost at various points along the flow path. For each collection system, key locations have are identified where temperature measurements are taken. There are fourteen such locations throughout all four systems. Four temperatures are measured on each system except for the control heater where only two measurements are taken.

VIRTUALBENCH OVERVIEW

The VirtualBench Logger software is used to measure the 14 critical temperatures throughout the three collector and one control heater systems. This program is responsible for logging temperature data measured at the various locations along the solar collector systems. This software accesses the NI-4351 High Precision Temperature Logger DAQ board from which measured voltages are converted to temperature measurements to be viewed and logged.

HARDWARE INTEGRATION

The VirtualBench Logger software, in conjunction with the NI-4351 High Precision Temperature Logger and the TBX-68T Connector Block, is responsible for logging and controlling all temperature measurements. The TBX-68T connector block has a total of 16 channels of which only 14 are available for temperature measurements. The two remaining channels provide cold junction compensation and autozeroing, which are used to correct for measurement errors caused by the ambient temperature and noise. For specific concerns regarding the instrumentation, it is recommended that the *NI-4351 Users Manual* be referenced.

Type E thermocouples are mounted with a reflective tape to the piping system at their key locations and then covered with insulation. The pigtail end of each thermocouple is wired directly into one of 14 open channels in the TBX-68T connector block where a voltage is measured and sent to the VirtualBench to be analyzed. The specific locations of the thermocouples can be referenced to in the *Solar Collector System Plumbing Diagram* where circled numbers ranging from 2 - 15 indicate the channel number into which that particular thermocouple is wired.

SOLAR COLLECTOR SYSTEM THERMOCOUPLE WIRING DIAGRAM

NI-4351 High Precision Temperature Logger TBX-68T Interface

Chapter 6

LabVIEW and Apollo.vi

LABVIEW

LabVIEW provides the environment under which the system software and hardware may function. The programming language G is an integral part of the LabVIEW environment and is the language that Virtual Instruments (or VI's) are created with.

Programming LabVIEW is analogous to creating an electronic instrument. There is a front panel that can be created where information is viewed and separately, there exists a wiring diagram where the functions of the instrument are programmed. This is done by selecting sub-VI's from various libraries and wiring them together using virtual wires.

APOLLO.VI VIRTUAL INSTRUMENT

The VI that was created for the Solar System is called Apollo.vi. This VI accesses DAQ boards installed within the central computer system (described in more detail in *Chapter 4: Electrical System*) where it collects information regarding the solar systems performance. This information is processed within the virtual instrument, shown in summary form in the front panel in real time, and periodically saved for future retrieval and analysis.

FRONT PANEL

The front panel of the Apollo.vi instruments allows the user to monitor the performance of each system in real time. This includes information regarding the flow of water through each system and power usage (temperatures are measured using a separate program).

Four separate graphs, each representing one system, display the actual flow rate of water through each system in comparison to a desired flow rate. This feature is useful in determining the proper functioning of each system. Additionally, the cumulative flow of water through each system is given in a digital display which aids in ensuring that the flow of water through each of the systems are nearly identical.

The electrical power usage of each system can also be monitored via a virtual LED and digital display. As described in Chapter 4, each of the power meters connected to the collector systems outputs a ± 10 VDC pulse. The change in polarity of the pulse is monitored by red and green LED's which alternate on and off to indicated power usage. The power usage for each meter is rated at 0.0003 Watts/pulse.

The front panel also incorporates an instrument On/Off in addition to date and time displays and a display indicating the path and filename to which data is being stored.

POWER MONITORING

Within the wiring of the Apollo.vi instrument are five components similar to that shown in the adjacent diagram. These components are responsible for measuring the ± 10 VDC pulse emitted from the power meters attached to each of the physical collector systems.

The lower portion of this component indicates that a measurement will be taken every 100ms or at a rate of 10 Hz. The frequency of the actual pulse is no more than 2 Hz, indicating that the 10 Hz is a sufficiently fast measurement rate.

The remaining portion of the component is wired to measure and determine a change in polarity of the pulse. Once a change in polarity takes place, this component sends information indicating that a 1/2-pulse change has occurred. This is multiplied by a factor of 0.0003 Watts/Pulse where after this information is sent off to be recorded.

FLOW CONTROL

The CSTRR and SRCC flow rate draw schedules are stored in the wiring diagram of the Apollo.vi instrument. These modules are placed outside of the main control loop and are referenced to during each main loop cycle.

Inside the loop are icons with the ability to reference a specified position within an array. The CSTRR and SRCC profiles are stored in an array of 24 values numbered from

0 to 23. Each array value corresponds to a particular hour in the day in military time. A clock within the main control loop looks up the hour of the day and sends this value to the array referencing icons. The corresponding value from the array is extracted and sent to one of four the feedback loop modules. Here, the value will be used as a reference value to maintain the appropriate flow rate through the collector systems.

DATA COLLECTION

The data storage portion of the Apollo.vi consists initially of setting up a file for data to be recorded to. A new file is automatically created every day to which data may be recorded. An example may be:

C:\windows\desktop\solar-05-31-00.dat

The date portion of each file indicates the day that data was recorded in the format of month-day-year.

Headers are also recorded into the file at the beginning of each day. The first heading indicates the date and time that data was recorded. Three more sections follow wherein the cumulative power usage of each system, the cumulative flow of water through each system, and the desired flow rate for a given time period are recorded.

Appropriate sub-headings are also included to distinguish between the various systems. The flow rate and rate of power usage may be extracted from this data as appropriate.

Data is recorded every 10 minutes beginning at 5 minutes after the hour. The various forms of data, including the power usage for each system, the cumulative flow rates for each system, and the desired flow rates are arranged into a single bundle and wired into the adjacent component. This component becomes active once every 10 minutes. It remains active until the presented bundle of data is recorded and becomes inactive again thereafter.

The left portion of this component indicates the time increments at which data is to be recorded.

The lower portion of the component indicates the path and filename to which data is to be recorded.

The nested loop portion of the component records data in a tab delimited fashion in the appropriate order.

Chapter 8

Maintenance

The entire solar collection system has been designed to be relatively maintenance free. There are, however, a few tasks worth noting to keep the system running at its optimal level.

SOLAR PANELS

In order to keep each system running at its prime, it is recommended that the aperture of each solar panel be washed periodically, ideally once every month when data is collected and after unusual weather conditions such as high winds or rain.

HELIODYNE SYSTEM

Because the Heliodyne system circulates an antifreeze solution at high temperatures through a closed loop pipe network, it has the potential to degrade and become more acidic. The pH of the antifreeze solution should be measured once a month.

The majority of public utilities supply water at a pH between 7.2 and 8.0. Water with a pH of less than 7 becomes increasingly acidic. Acid water dissolves metal and shortens the life of plumbing. As a common general guideline, copper should not be installed if the water has a pH of 6.5 or less. When this is the case, the antifreeze solution should be replaced.

Additionally, the pressure of the antifreeze loop should be checked to make sure that it's maintaining some degree of pressure. If the pressure drops below 20 psi, it should be pressurized and checked for system leaks.

POWER OUTAGE

The entire system should be checked once a week to assure that it is still functioning. In the unlikely event of a power outage, the entire system will shut down. In this case, the computer system should be rebooted and restarted using the guidelines in *Chapter 8: System Initialization*.

SYSTEM CALIBRATION

Periodically, the FP-5061 Micro-Flow Sensors and the Sea-Metrics SPX Low Flow Sensors should be calibrated to assure that they are accurately measuring the flow rate through each system. This calibration is critical since these meters are the only means by which the flow rate and cumulative flow through the systems are measured.

Each flow meter may be individually calibrated using the "Valve Calibration.vi" program. This program allows the user to access each of the flow meters individually. The user may also control the flow rate of water through each system by varying the voltage sent to the feedback control valve associated with each flow meter.

Several guidelines regarding the FP-5061 Valve Calibration instrument are as follows:

Each flow meter is attached to either Device #2 or Device #3 and also on Channel #0 or Channel #1 of each device. There are 4 flow meters in total whose address are labeled as follows:

- Sun System SRCC - Device #2, Channel #0
- Sun System CSTRR - Device #3, Channel #1
- Heliodyne System - Device #2, Channel #1
- Control Heater - Device #3, Channel #0

1. In order to calibrate a specific flow meter, all of the control valves should be initially closed. This means that each valve should be manually shut-off using a flat head screwdriver prior to each calibration test.
2. Enter in the required testing parameters. These include:
 - Test length - The amount of time in seconds for which the test is to run.
 - Device Number - As indicated by the flow meter address.
 - Channel Number - As indicated by the flow meter address.
 - Valve Voltage - Each control valve operates on a 0 - 5 VDC signal. 0 = Fully Closed, 1 = Fully Open. Choose a flow rate based on this voltage range. (Note: The valve is not linear. Most of the action takes place at lower voltages when the valve is first opened.)
3. In order to begin the test push the ON button. The valve will open and the flow meter will begin to register pulses. Collect the water and compare the collected amount to the # of registered pulses. This will give a calibration factor (K-Factor) of (Pulses/Gallon) for each meter. The factory shipped K-Factor for the FP-5061 is 9950 Pulses/Gallon.

Because the flow rate of water through each system is a constant 11.5164 gallons/hour or 0.7266 liters/minute, the flow meters should be calibrated for this flow rate. Because the control valves have a limited resolution, it is unlikely that the exact desired flow rate will be achieved. It is therefore suggested the several data points closely surrounding this flow rate be collected and a linear regression performed to extract the desired K-Factor for each flow meter. The flow meters are non-linear in nature so data closely surrounding the desired flow rate is desirable.