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Assembly and Comparison of Available Solar Hot Water System Reliability Databases and Information

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Assembly and Comparison of Available Solar Hot Water System Reliability Databases and Information*

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Sandia Purchase Order No. 836745

Abstract

Solar hot water (SHW) systems have been installed commercially for over 30 years, yet few quantitative details are known about their reliability. This report describes a comprehensive analysis of all of the known major previous research and data regarding the reliability of SHW systems and components. Some important conclusions emerged. First, based on a detailed inspection of ten-year-old systems in Florida, about half of active systems can be expected to fail within a ten-year period. Second, valves were identified as the probable cause of a majority of active SHW failures. Third, passive integral and thermosiphon SHW systems have much lower failure rates than active ones, probably due to their simple design that employs few mechanical parts. Fourth, it is probable that the existing data about reliability do not reveal the full extent of fielded system failures because most of the data were based on trouble calls. Often an SHW system owner is not aware of a failure because the backup system silently continues to produce hot water. Thus, a repair event may not be generated in a timely manner, if at all. This final report for the project provides all of the pertinent details about this study, including the source of the data, the techniques to assure their quality before analysis, the organization of the data into perhaps the most comprehensive reliability database in existence, a detailed statistical analysis, and a list of recommendations for additional critical work. Important recommendations include the inclusion of an alarm on SHW systems to identify a failed system, the need for a scientifically designed study to collect high-quality reliability data that will lead to design improvements and lower costs, and accelerated testing of components that are identified as highly problematic.

* The work described in this report was performed for Sandia National Laboratories under Purchase Order No. 836745.

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Greg Kolb sponsored this work and provided many valuable comments, ideas, and other technical guidance. Jay Burch offered suggestions for analysis and provided some of the data used in this work. Cliff Murley provided a detailed review of the critical portions of the report's analysis section, much of which focused on data collected by the Sacramento Municipal Utility District in the 1990s. Special acknowledgment goes to Jim Huggins and John Harrison. Jim responded to various queries with detailed information. John Harrison was especially helpful, considerate, and thorough in his responses, and he provided much of the data used in this study. John spent many hours in phone and email conversations with the author to ensure a complete understanding about the information that he had supplied and in reviewing the final draft. The author extends his gratitude to all of these individuals.

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ACRONYMS

ASU	Arizona State University
DOE	Department of Energy
FSEC	Florida Solar Energy Center
HECO	Hawaiian Electric Company
ICS	Integral Collector System
MTBF	mean time between failures
NAHB	National Association of Home Builders
NREL	National Renewable Energy Laboratory
PV	photovoltaic
SHW	solar hot water
SMUD	Sacramento Municipal Utility District
SNL	Sandia National Laboratories
SRCC	Solar Rating Certification Corporation
SWAP	Solar Weatherization Assistance Program
UV	ultraviolet

1. INTRODUCTION

The reliability of solar hot water (SHW) systems has been in question for many years. The matter is not necessarily focused on concerns about low quality, although that is always a question with mechanical products. Rather the issue is that there has been a dearth of high-quality reliability information. For years the actual reliability of these systems was simply unknown.

Many people, especially Jay Burch at the National Renewable Energy Laboratory (NREL), have continued to present a strong case that systematic improvements—which are always possible in any mechanical system—depend on the identification of weak components and design flaws. These problems cannot be identified without seeking them out and carefully measuring them.

While the energy performance of SHW systems has consumed the industry, no known scientifically designed, well-controlled studies have been done to allow a thorough analysis of SHW reliability. Energy performance information is important and can suggest reliability shortcomings, but it is not synonymous with reliability information. Performance data can provide information about a system's startup and failure dates and sometimes document its degradation over time. What performance data rarely provide, however, is information about how and why a system failed, which is critical to future improvements. A properly conducted reliability study would quantify the lifetime of major components, identify poor designs, and suggest improvements that would extend overall system life and reduce costs.

Over the past 30 years there has been a general lack of support for comprehensive reliability studies. One can speculate about the foundations for this resistance, but the result is that *high-quality* reliability data are quite limited.

However, reliability data do exist in some form; some are based on surveys and others come from repair records. Some of the studies associated with these data have produced interesting and useful results. No known work has examined all of the available data in a comprehensive manner, one that compares the various datasets for accuracy, consistency, and commonality.

These questions beg answers: Do all of these different existing studies lead to the same conclusions? Is there consistency between data collected by the method of surveying versus ones based on actual service records? Does a comprehensive review of all the available data produce any new implications for improving SHW products?

The purposes of this study are to:

- Identify and procure as much of the available SHW reliability data as possible
- Organize and place the data from the various datasets into a single database with a common format
- Summarize the data and compare the summary statistics among the various groups of data within the database
- Analyze the data to the extent possible to derive more information
- Forge recommendation for future action
- Document the results

This study does not address costs.

The remainder of this report is divided into the following sections. Section 2, Historical Perspective, provides a brief review of SHW industry evolutions. Section 3, General Information About Reliability Data, discusses the various types of reliability data and the typical metrics used to define reliability. Section 4, Data Collection and Procurement, discusses the various sources of data and the data that were actually procured. Section 5, The Combined Reliability Database, describes how the database was created and organized. The database in its entirety accompanies the electronic version of this report and is available electronically (see below for link). In Section 6, Discussion of Related and Ancillary Studies, pervious work and analyses are discussed. Section 7, Comparisons and Analysis of Database, contains discussion and many graphics comparing the various measures of reliability among the different sources of data. Section 8, Conclusions and Recommendations, presents the summary of major findings from this study along with recommendations for controlled studies of SHW reliability.

For clarity throughout the report, the term "database" refers to the Excel spreadsheet and its worksheets that were created in this project. The term "dataset" refers to the individual sets of data that were received from one of the sources.

Appendix A contains a bibliography of materials that were used in the study or were related to it. Appendix B contains copies of the four most important studies relating to this work; all included in their entirety with permission of the authors or copyright holders. Appendix C contains a printed copy of the database. An electronic version of the database can be obtained at http://www.sandia.gov/Renewable_Energy/excel/Reliability%20database.xls.

2. HISTORICAL PERSPECTIVE

Solar hot water (SHW) systems have existed in the United States since the late 1800s. Most of the early systems were simple batch water heaters consisting of a black-painted water storage tank housed inside of an insulated box with a glazing on one side to allow solar radiation to enter. Essentially the tank acted as a repository for hot water that could be used domestically. When applied, it was usually the only source of water heating in the structure (other than the old-fashioned technique of heating a pot of water on the stove).

Through the early part of the 20th century SHW systems slowly began to gain favor as water plumbing became a standard feature in new buildings. However, by the second decade the distribution of natural gas and electricity began to burgeon in major population areas. Mass-produced gas and electric water heaters quickly eclipsed solar systems as the equipment of choice for heating water in commercial, industrial, and domestic settings.

The Arab Oil Embargo in the early 1970s brought public attention to the perils of a national dependence on finite supplies of fossil fuels. The embargo-generated panic produced increasing interest in alternative energy sources, such as solar and wind. The federal and state governments responded with a surge of incentives and funding for renewable technology.

Solar hot water was one of the first solar technologies to emerge as a commercially viable product. By the late 1970s a host of SHW manufacturers were operating in full production, most of them producing systems for domestic and pool water heating. Some of these companies are still operating today.

However, starting in 1980 and for two following decades, the effect of the embargo waned, fossil energy prices settled at affordable levels, and a deregulated market seemed to stabilize fossil-product supplies to easily match steadily growing demand. Government assistance for solar technology dwindled and the SHW industry struggled to compete in the hot water market dominated by relatively low-cost gas- and electrically fired water heaters. Many solar manufacturers failed.

Those SHW companies that remained at the outset of the 21st century produced mostly domestic or pool water heaters using technologies that had not fundamentally changed since their inception. Flat-panel collectors—both glazed and unglazed—and batch heating devices dominated the SHW industry. Over the years SHW systems have seen incremental improvements in manufacturing quality (e.g., welding and brazing), materials (especially ultraviolet [UV] resistant polymers), and component selection such as improved pumps and valves.

The only truly new product was developed early in this century. NREL, working with its contractors, produced a polymer collector, the first of its kind. Although the system is certified by the Solar Rating Certification Corporation (SRCC), few of these systems have been installed commercially.

The SHW industry was largely sustained over these difficult decades with a steady stream of individual sales to environmentally conscious home and small-business owners. Additionally, a few large-scale purchases of domestic SHW systems buoyed the industry. Some of these programs were organized through forward-thinking public utilities such as the Sacramento Municipal Utility District (SMUD) or public programs such as the Federal Weatherization Assistance Program.

In the mid 1980s the industry was sufficiently robust to collaborate with universities and federal labs in organizing the SRCC to independently test and certify the performance of SHW collectors and systems. SRCC provides an invaluable service to the industry by quantifying the energy performance of collectors under carefully controlled conditions. The SRCC certification has elevated the status of the SHW industry's products to a level akin to other certified mechanical and electrical products, such as those listed by Underwriters Laboratories, Inc. (UL).

As part of the certification process, the SRCC laboratories perform some initial durability tests and review system designs for potential flaws. If the systems meet the SRCC standards, they are awarded a certification. While these durability tests are useful to identify early failures, they do little to quantify long-term potential reliability, especially that of the SHW system's components.

3. GENERAL INFORMATION ABOUT RELIABILITY DATA

Mechanical equipment has existed for centuries and there exists a long history of measuring, collecting, recording, and analyzing reliability information. There are four principal measures of reliability that are typically used. The most common, according to Carl Hiller, a mechanical equipment reliability expert, is *service life*. Hiller (2000) states that "scientifically obtained mean *service life* data is derived from a study of actual equipment installation and removal dates." It is always a temporal metric and is defined as the age at which 50% of equipment is still in use and 50% has been replaced. From service life the mean time between failures (MTBF) can be computed. The MTBF is an important measure that can be used to improve systems, components, and fix warranty schedules.

Other measures of component reliability include *time to first failure*, the *reliability index*, and *counts of total failures*. The *time to first failure* is similar to the service life but measures the average elapsed time to when the first component of its type fails. The *reliability index* is usually a nonparametric estimate of reliability that ranges from 0 (fails immediately) to 10 (never fails). In some engineering fields it is a computed measure. In other engineering areas it is a qualitative estimate produced from human judgment.

The fourth measure, *counts*, is a simple total of:

1. the failures of a specific system;
2. the failures of a specific system type or class;
3. the failures of certain components within a specific system;
4. the failures of certain components within a specific system type or class of systems; and
5. the failures of certain component in all systems.

Most of the existing SHW reliability field data has been collected as an indirect result of routine installation and maintenance of systems, rather than from studies designed to answer specific reliability questions.

For example, between 1990 and 1999 SMUD oversaw the installation of over 3,000 SHW systems in Sacramento. As part of the program they hired a solar contractor to provide service for these systems. This contractor kept records on the repairs and this information was collected by NREL. It has been useful in providing reliability information.

SMUD oversaw the installation of thousands of SHW systems during the 1990s and had contracts with Bergquam Energy to perform repairs as needed. As repairs were made, descriptions of the work were recorded. SMUD repair records contained information on system types. Also, SMUD kept a record of total installations sorted by system type.

Murray & SUN, another Sacramento area solar contractor, repaired other solar systems in the Sacramento area and kept records of them. However, the records of these repairs that were available for this report do not have an indication of system type. However, solar pool system repairs were differentiated from SHW system repairs. There is no record of the population of total SHW/pool installations that existed in the area serviced by Murray & SUN.

In total, the Bergquam and Murray records totaled 1,130, and henceforth in this report, the SMUD records originating from Bergquam are referred to as "SMUD," the Murray data are called "Murray," and the grouped data (Bergquam plus Murray records) are referred to as "Sacramento."

There are shortcomings in using repair records for reliability analysis. First, the repair records are not always consistent in format. Some records describe the type of system under repair, its installation date, and the details about the corrective action. Other records report only the corrective action in general terms with no technical details.

Second, repair records can fail to identify some nonoperational systems because the system owner must call for service in order to create a record. Solar systems always have fossil or electric water heating backup systems. A SHW system could silently fail and a nonobservant owner may never notice its nonoperational status. Even if a failure is noticed, some owners may decline to call for service because hot water is still being produced by the backup system.

Third, these data do not represent a random sampling of the population of all installed SHW systems and therefore could contain biases due to the prevalence of certain systems that had a propensity for failure or problems. Simply stated, problematic systems are the ones that make their way into the repair records. A particularly unreliable system type could skew the data with an extraordinarily high number of failures for certain components. For example, quickly perusing the raw data service records from SMUD shows that one particular system type required repair at a high rate. Eventually, that system model ceased to be installed because the manufacturer closed the business, but its reliability legacy lives in the historical data.

Another approach to collecting reliability data is to conduct surveys of knowledgeable SHW industry experts. They can be asked for their opinion about the lifetime of components and other problems. This is a low-cost method of obtaining reliability information, but it has its shortcomings.

Hiller (2000) identified three problems with this survey approach: "First, if the respondent has not maintained actual installation and removal data for the equipment over a long period of time, and has not performed the rigorous mathematical analyses necessary to determine equipment survival rates, the respondent will be unable to state with certainty what percentage of units have been replaced at any given age. That person most likely will provide an opinion of how long equipment lasts based on the individual's experience with equipment removed from service—with little regard for equipment still in use. At best, opinion surveys only can produce age at replacement information. Age at replacement information and service life information are not identical."

"Second, many equipment types have service lives longer than the typical career span of a person in the industry. This means that a respondent often relies on 'second-hand' information unless the firm has long-term records of equipment installation and removal dates, and the individual has used proper procedures to analyze the data."

"Third, opinions are easily swayed by rumor, exaggeration, and false advertising."

Another reason is that every industry representative is inherently biased in favor of his or her products and against the competitor's products. Furthermore, some manufacturers have accurate information based on warranty claims but are reluctant to make it public due to business concerns.

A different type of survey is one of physically inspecting installed systems. Typically these inspections are done at some fixed periods after the installation. In this case a trained technician visits each installation site, determines the condition of the system, and carefully documents the problems. If the inspection interval is sufficiently short, reasonably accurate service life information can be obtained for systems and components.

However, the approach is expensive and time-consuming and there have been limited attempts to collect data in this manner. In 2003 the Florida Solar Energy Center (FSEC) conducted a field survey of 151 SHW systems installed ten years previous as part of the Federal Solar Weatherization Assistance Program (SWAP). The data they collected is among the most detailed and accurate in existence, but it is limited in that it was a single, one-time visit to the installations and the exact failure dates for some equipment could not be determined because it was not known how long dead equipment had been inoperative.

The FSEC and Sacramento data are the most recent measures of SHW reliability data that are known to exist. More recent data are likely to exist in the files of contractors and manufacturers, but they are not readily accessible. Importantly, neither database contains information on the age of the components that failed, a critical statistic for reliability analysis.

The age of the existing data is of some concern. Both the FSEC and Sacramento data have measures of failures in systems that were built in the 1990s, eight to seventeen years ago. While systems have not substantially changed in configuration over the years, manufacturers do make incremental improvements over time, especially if a certain component becomes an expensive warranty-service issue. As the industry grows, as it is growing now, there is competitive pressure to reduce costs but keep quality as high as possible. Therefore, manufacturers look to improve their products and reduce costs, and these changes can sometimes result in improved reliability. Contractors and installers also learn how to build and install systems that have fewer problems, especially regarding initial failures that require contractor "call-backs" to the site, an event that every installer wants to avoid. Finally, competitive pressures tend to drive bad products off the market over time.

It is logical, therefore, to conclude that the existing SHW products are the best they have ever been, even if marginally so. It follows, then, that reliability estimates taken from systems ranging in age from 15 to 20 years might be somewhat more pessimistic relative to the newest systems.[†] However, the various other shortcomings, as discussed in detail above, probably overwhelm the magnitude of this potential bias and can probably be ignored as a concern within this study.

[†] According the John Harrison, of the FSEC (an SRCC test lab), in the Orlando area there have been few changes in the style, quality and performance of many of the components used in many SHW systems over the past decade.

4. DATA COLLECTION AND PROCUREMENT

Sources of Data

This part of the study began by identifying potential sources of reliability data. This investigation included phone calls and follow-ups to organizations who have been involved in SHW and who were likely to have information on system reliability.

The principal organizations contacted included:

- Solar Rating Certification Corporation (SRCC)
- Hawaiian Electric Company (HECO)
- National Renewable Energy Lab (NREL)
- Salt River Project
- Arizona Public Service
- Sacramento Municipal Utility District (SMUD)
- Solar Energy Industries Association
- Florida Solar Energy Center (FSEC)
- US H2O
- Maui Community College
- Hawaii Natural Energy Institute
- Colorado State University
- Virginia Tech University
- National Association of Home Builders (NAHB)
- Pulte Homes
- Building Sciences Corporation
- Bergquam Energy
- Multiple SHW manufacturers and vendors

Although it is possible that some data sources were not identified, it is probable that most of the major sources of information are contained on this list.[‡]

In addition to the personal contacts, a literature search was conducted at the University of New Mexico Centennial library and via the internet. Many documents were tagged as relating to SHW reliability, but only 15 were identified as having reasonable significance to this effort. The titles of these documents are found in Appendix A.

‡ Several people who reviewed this document before publication noted additional sources of information, including Florida Power & Light and Eugene Water & Electric, both of which have overseen the installation of many SHW systems and may have reliability information. Contractual limitation of this study prevented these sources from being contacted at this time. However, they will be included in any follow-on study, if one is implemented.

Data Procurement

Three of the sources provided raw data (i.e., copies of actual records of SWH repairs): HECO, NREL (hard copies of repair data from SMUD), and the FSEC, who provided Sacramento repair records as well as data from the SWAP program, a program that FSEC managed for the Department of Energy (DOE).

The HECO data consisted of only 19 hard repair records and a summary presentation by Ron Richmond (Richmond 2005). NREL supplied six hard-copy binders of miscellaneous records of information, including SMUD repair records. FSEC supplied 1,130 records of SHW records from Sacramento and 151 records from the SWAP.

The 151 SWAP records originated from a survey of installed systems that FSEC conducted in 2003. Over 800 SWAP SHW systems were installed in the early 1990s. In 2003, FSEC inspected 151 of these systems and documented their operational status. These data were supplied for this project. The SWAP dataset was entirely in the form of hard copies and all records were provided for this project.

Several years ago NREL procured copies of the Bergquam and Murray repair records and supplied copies of them to FSEC. In total there were 1,130 of these records. At the outset of this project, NREL had 548 of the Bergquam repair records in their dataset, all in hard-copy form. NREL also had other data and SHW reliability analysis reports. NREL supplied all of their data and information for this project.[§]

FSEC had previously synthesized all 1,130 Bergquam and Murray records into an Excel spreadsheet and they provided that spreadsheet for use in this project. Although many of these records related to systems that were not installed under the SMUD program (including the Murray records), all were installed in the Sacramento area.

The 548 hard-copy records of the SMUD data were to be used as a quality check on the tabled data that FSEC supplied.

Jim Bergquam supplied information about the total number of installed systems in the SMUD area during the 1990s. These data were used in this study to compute the proportion of systems that had failed in the SMUD area.

Industry survey data and reports were obtained from Arizona State University (ASU), FSEC, and NREL. In all three studies SHW manufacturers and installers were asked their opinion about the reliability of SHW components and systems.

[§] Some of the SMUD-managed installations—those before 1992—were not SRCC certified. It would be interesting to assess whether any quality differences could be discerned between noncertified systems and the later ones, all of which were certified. However, the data do not contain the resolution and detail to allow such a comparison.

The ASU study was funded by NREL and was supervised by Professor Byard Wood of the ASU Mechanical Engineering Department. The report presents three principal measures of reliability—lifetime, time to first failure, and reliability index—for many SHW system components. In this study, Wood and his team surveyed 28 existing SHW manufacturers and installers. The survey questionnaire asked for opinions about the reliability of various components of SHW systems.

The NREL survey, conducted in 1994 by Jay Burch, and the FSEC survey, conducted by John Harrison in 1993, are similar.

The NREL survey contains component service life information based on opinions from eight Sacramento-area SHW contractors and manufacturers. The FSEC study also produced component lifetime estimates based on opinions from five Florida contractors. This work was done in preparation for the SWAP, a pilot effort in Florida.

The result of the FSEC survey was a table of estimated lifetimes for various SHW components. Since no accompanying report was available to explain the details, John Harrison was contacted directly for information. He said that the study was informal and intended to produce preliminary and rough estimates of the average life of components. Although these are not service life estimates, they are still of value.

In all three industry survey reports, there is no breakout for different system types. Presumably, life and reliability estimates are meant to represent all systems. It is not clear what the mix of system types might have been in the imagination of the interviewees as they were estimating the various lifetime and reliability estimates. This situation creates uncertainty and potentially large variance that should be considered as they are applied.

All three survey studies were successfully procured for use in this project.

NREL had conducted another reliability study, records from which were included in the hard-copy information that NREL had supplied for this project. A pie chart resulting from that NREL effort summarized a survey of 185 solar systems; the chart indicated the number and types of problems that had been identified. The data appeared to be candidates for inclusion in the database, but with no accompanying report, it was impossible to verify the source of the data or the type of survey methods used, or to ensure that that they were unique from the other data that that was to be included in the database.

The best source for this verification was Russ Hewett (retired), NREL's principal investigator for the study. After discussions with him, it remained unclear as to the exact source of the data but that it was probable that they were derived from the SMUD records. Therefore, for completeness these data were procured for the project, but were not expected to be included in the analysis or discussions.

Miscellaneous summary data from several other sources were available, but they are not significant due to limited number and questionable accuracy. Therefore they were not procured.

Some specific solar-related corrosion information was collected from several sources, and these are included in the bibliographic listed in this report. The most significant of these were reports produced by Sandia National Laboratories (SNL).

All of the records procured for this study related to SHW installations in the 1990s. The SWAP survey, however, was conducted in 2003. No more recent data could be found.

Personal consulting contacts regarding reliability were also arranged. The names and professional affiliations are found in Appendix A, subsection Consultants. Some of these individuals, especially John Harrison and Jim Huggins of FSEC and Jay Burch of NREL, contributed considerable information, advice, documentation, and guidance.

Section 6 of this report contains more information about previous analysis and reports relating to some of the datasets that were discussed above.

5. THE COMBINED RELIABILITY DATABASE

The data that were procured fell into two basic groups: (1) repair records and inspection records of actual systems and (2) results of surveys of industry members.

The goal of this part of the project was to design and construct the database for both sets of data. As this effort is being discussed, it might be useful to the reader to have the Excel database available to review. The database can be downloaded using http://www.sandia.gov/Renewable_Energy/excel/Reliability%20database.xls.

The development of the database used to contain the datasets of repair and inspection records follows directly below. The design of the database used to contain the datasets from the industry surveys is described later in this section.

The Database Structure for the Repair and Inspection Records

The first task was to define common categories for all the component types. Common categories were needed to facilitate comparisons among the various data sources.

Common categories were selected for the various component types by reviewing the categories that were listed in the source datasets and then selecting an optimal number of categories that represented all of them. Eight categories were selected:

- *Collector*—includes any measure of the collector and its components, including mounting issues.
- *Controller*—includes data for any control mechanism for an active system, but not the sensors.
- *Sensor*—includes all of the sensors involved with the operation and control of the system, but not the energy performance monitoring sensors.[**]
- *Tank*—includes information about storage tanks and heating tanks, but not tanks that are integral to the collector, as in a batch system.
- *Pump*—includes all information about pumps of all kinds.
- *Heat transfer;* includes various different items that relate to the transfer of heat from one part of the system to another, including fluids and heat exchangers.
- *Piping*—includes information about the piping itself as well as connectors, mounting techniques, and insulation.
- *Valves*—includes information about valves including manual and electrical ones, vents, emergency valves, drain valves, etc.

All the data—surveys and repair records—were fitted into these categories. In some cases best judgments were applied to determine the appropriate category to place an item, but in the large

[**] Monitoring sensors are not included because they are not critical to the operation of the system. A failure of one of these sensors will not disable the system as would a failure of sensors that are critical to its operations, such as the ones used to measure the temperature of the storage tank and the collector.

majority of cases the categories selected for this study were very similar or identical to the ones in the source datasets. Therefore minimal manipulation of the original data was needed.

The next step was to select system-type descriptors. Most of the repair or survey records described the type of solar system that was installed along with the problems that were identified.

Systems were described in various ways throughout the records. Some were clear, such as "ICS," the integral type. Others were more cryptic, such as "drainback-draindown." A system can be one or the other, but it is inconceivable how it could be both.

Others were consolidated where it made sense to do so. For example, a "pumped system" and a "pumped direct system" were assumed to be the same system type, a "pumped system."[††] After thoroughly reviewing the raw data, the following system-type categories were selected:

- Integral Collector System (ICS)
- Pumped
- Thermosiphon
- Photovoltaic (PV) controlled pump
- Pool
- Unknown

The ICS category contains only ICS systems. The pumped category contains all types of systems that use pumps to circulate a fluid through the collector, except PV-pumped systems. The thermosiphon category contains traditional thermosiphon systems along with similar ones, such as the Copper Cricket, a system that uses thermosiphoning principles to drive a phase-changing fluid through the collector. PV-controlled systems are pumped systems that use photovoltaic panels to power the pump and control the flow. The pool category contains all types of solar pool water heaters. All information that is not clearly associated with a specific system type is placed in the category called "unknown."

With the component and system-type categories selected, the attention turned to the design of the database itself. After discussing the possible database structure with Greg Kolb of SNL and Jay Burch of NREL, a hierarchical design was adopted.

The most detailed data provide the foundation of the database. Subsequent rollups summarize the information into higher-level categories. For example, within the general area of "collectors," a high-level category, there are many failure possibilities involving the collector itself as well as collector mounting system. With respect to the collector itself, failure could result from a leaking absorber, broken glazing, clogged header, etc. These are referred to as subcategories. A collector mounting issue could involve improper orientation or tilt, poor flashings that caused roof leaks, etc.

[††] Pumped systems are typically classified as direct or indirect. In a direct system, city water is heated directly within the collector and delivered to a single hot water heater. In an indirect system, the collector fluid is self-contained and the domestic supply water is heated via an intermediate heat exchanger. Indirect systems are more complex than direct systems because they use multiple tanks and pump loops, but they are more freeze-tolerant.

Therefore, at the most detailed database level, the general collector category is divided in two: "Collector problems" and "Collector mounting problems." Under each of these two categories are the numerous subcategories that describe the specific problems. The most rudimentary level of the record detail contains as much information as was available in the raw data reports.

At the next level of detail, called a "mid level summary," the totals from the two collector categories are summarized and rolled up into a higher-level database. For example, in this mid-level database, only two entries appear under the broad category of "collectors": "Collector problems" (labeled "faulty collector problems") and "Collector mounting problems."

At the highest level, called the "hi level summary," the collector problem totals are rolled up into a single category called "collectors," which contains a summary total of all the collector problems. At this level there is only a single entry—a number that represents the total problems in the category of "collectors."

For example, the hierarchy for collectors looks like this:

Collector (highest rollup level)

- Collector problems (middle rollup level)
  - Defective collector (detailed level)
  - Leaking collector (detailed level)
  - Header tube leaking (detailed level)
  - Riser tube leaking (detailed level)
  - Etc.

- Collector mounting problems (middle rollup level)
  - Collector not firmly attached to roof (detailed level)
  - Mounting bolts not secured (detailed level)
  - Improper structural mounting (detailed level)
  - Improper roof flashing (detailed level)
  - Etc.

The other major component categories are constructed in similar fashion to the collector category.

The convolution of the problem categories and the system types results in a two-dimensional data matrix. Along the ordinate, or each row of the Excel spreadsheet, are the labels for the various problem categories. Along the abscissa, or each column in the spreadsheet, are the labels for the system-type categories. The cells that intersect the rows and columns are the number of instances in which a problem was recorded.

These counts are the basic, final statistic in the database. They are single summary values that represent the whole population of counts that exist in the records. Averaging is done across the categories where it is sensible, but the average then represents the average count of problems that were reported in that category.

Summary rows are interspersed in the data, corresponding to the higher-level category, i.e., they contain the rollup numbers. Column totals (the right-most column) presents the total number of problems for all the collector types.

A complete database for the field data contains three spreadsheets, one that has detailed summary information (worksheets labeled "detail sum"), one that contains the next level of rollups, called the mid-level summary (worksheets labeled "mid level sum"), and one that has the final rollups, called the high-level summary (worksheet labeled "hi level sum.")

A higher-level rollup is possible that would summarize the system types into a single generic system type, resulting in a vector array. However, since many problems are typical for certain types of systems and some problems are impossible for other types, this summary was not included it because it would probably be misleading. For example, ICS systems have no pumps, so they can have no pump problems. If these systems are rolled up with pumped systems and other types that contain pumps, the resulting summary data would probably lack meaning.

Because there were three major sources of repair data—Sacramento, SWAP, HECO—a tri-level database structure was created to contain each dataset. The result is potentially nine worksheets.

A tenth worksheet is a rollup of the three high-level worksheets for each data source (worksheet labeled "Combo hi level sum"). The format for this highest-level worksheet is identical to the high-level summary worksheets, but each cell contains the total number of occurrences of problems for all three dataset sources.

The Database Structure for the Industry Survey Records

The basic structure adopted for the service records was applied to the survey data. The basic datum in the database is an estimate of time or the reliability index. The identical component and system description categories constituted the basic database structure. As noted earlier in this report, these three datasets did not break out the data by system type.

Two levels of details were created and represented in the database worksheets: Detailed level and hi level sum. The detailed level worksheet (labeled "…survey detailed") contains the raw data as presented by the investigators. Many of the investigators' component categories matched nearly identically with the ones chosen for this database. But some rearranging was required. Some data were totally missing. For example, the FSEC dataset contained no data for sensors; this information was probably integrated into a different category. It was ignored in this database.

The data from the detailed worksheets were rolled up to the highest-level worksheets (labeled "survey hi level sum").

Data Quality Assurance

Because the data were in various formats and configurations, the quality assurance step consisted of visually inspecting the records to identify inconsistencies and other obvious errors.
The digital datasets that FSEC supplied were inspected before they were included into the database. Potential inconsistencies were resolved in phone conversation with FSEC personnel. For example, in some instances it appeared that there was more than one problem per record, which might appear to be counterintuitive. But after discussion with John Harrison at FSEC, he explained that it was frequently the case that technicians found more than a single problem in a service call; thus these entries were probably valid.

Similarly, sometimes the technician found no problem with the solar system. Such a case might happen when a controller was turned off or the system was valved off. In these cases, the systems were indeed operational, but not operating. Its status was not due to a mechanical failure, but probably an erroneous human intervention.

NREL had supplied 548 hard-copy records of SMUD repairs. Each of these hard-copy records was examined to ensure that its noted problem category was listed in the database worksheet that contained the FSEC dataset. There is no identifier in the FSEC records, such as a date, that ties the data in the table to the original service records. Since it was impossible to know for certain whether a specific hard-copy record was included in the numbers that FSEC supplied, this was the only check that could be made. Basically, the best that one could do was to a search for inconsistencies that might flag quality problems, such as possible duplicate entries.

Similarly inspected were the SWAP and HECO repair records as well as all the data from the industry surveys.

Generally the repair data entered into the database were found to be reasonably consistent.

The quality assurance efforts also help to enhance the credibility of the data. In total, the database lends itself to further analysis and scrutiny for a broad range of systems and applications, which heretofore was very difficult.

Data Entry

Initially, the database was configured as described above, with all the cells blank. The subcategories below the major categories were left to be defined as the database was populated. For example, if a repair record indicated that the solar system failed because of a check valve problem and a “check valve” category did not currently exist in the database under the main category of “valve,” then one was created. Because the worksheets were all linked, all dependent worksheets were updated accordingly.

Unfortunately, this was a laborious, manual process because the worksheet linking system was insufficiently robust to automatically create these new rows of data in the other worksheets. Much of FSEC’s Sacramento table was imported using the import feature in Excel.

Hard-copy records from the SWAP and HECO were entered by hand after reading each record and applying the quality assurance methods noted above.

The HECO data were not in sufficient detail to warrant a detailed summary worksheet. Therefore, the HECO dataset only resulted in two levels of detail in the database and therefore only two worksheets, the "mid level sum" and the "hi level sum."

The worksheets were carefully checked for accuracy as they were built. Checksums were applied, which totaled the data in different ways, to compare with the column and row totals. These sums had to match across the appropriate worksheets at all times; a mismatch was a flag for a problem. The worksheet links were frequently checked during the populating process to ensure that changes at the bottom levels were properly reflected at the higher levels.

The highest-level Excel rollup spreadsheet for the repair data is named "Combo hi level sum" and was populated with the data from the three "hi level sum" worksheets.

Statistical Information in the Database

Some statistical information is included in the worksheets, mostly for quality assurance but also for subsequent comparison analysis. For example, since the total number of service calls was known, the number of problems per service call should generally be close to one. It is conceivable that more than one problem might be discovered in a problematic system, as Harrison suggested, but that is probably the exception rather than the rule. In the Sacramento hi level summary worksheet, the row labeled "Problems per service call" shows the number of problems encountered per service call per system type. The average number of problems per all service calls is 1.2, close to the expected value of 1.0.

Further examination of these data shows that pumped systems experienced multiple problems per service call. Again, this is expected because these systems contain many mechanical components that can fail. The ICS systems, on the other hand, show less than one problem per service call, indicating that frequently the service call did not find a problem and it might have been that an operational system was for some reason deliberately taken out of service.

The other statistics include a matrix titled "Problems as a percent of total." These values quickly show, by system, the components that have been most problematic, at least during the 1990s when most of these systems were installed. These data also serve as a quality check. For example, since integral collectors essentially consist of a collector, a few valves, and piping, an accurate database should not reflect problems in other categories. Indeed, the only problems that are noted for the ICS systems lay in the collector, piping, and valve categories, with the large majority in the collector area—just as expected. This is evidence that the data are reasonable and accurate.

The total number of SMUD system installations is precisely known for the ICS, Pumped, and Thermosiphon systems. These totals are noted in the row labeled "Total installations." In the database, the SMUD records from Bergquam are clearly differentiated from the other Sacramento records from Murray.

Using these totals, two important statistics are computed: "Percent of total installations," which is computed by dividing the total installed of each system type by the total number of all system installed, and "Proportion of problems as a % of total installed," which is computed by dividing the total number of service calls by the total number installed. This proportion relates the approximate percentage of fielded systems that have experienced problems within the period of record, 1990–1999. It should be noted that "service call" totals is used in the computation of the proportion instead of "total problems" because it is the basic response to a problem with a system.[‡‡]

Presumably, a single service call resulted in a repaired system, regardless of how many problems were involved. Even in the case of an operational system that erroneously generated a service call, a technician was still dispatched to the scene to bring the system back on line or to explain its operation to the owner. Both statistics are useful for understanding the problematic tendency of the various system types.

The SWAP database worksheets are constructed similarly to those of Sacramento's and many similar statistics are presented. However, there is an important, but subtle difference between the two. SMUD repair records are based on both service calls and a few inspections conducted by SMUD. The exact proportion of service call based data and inspection data could not be differentiated in the data used in this investigation. Service calls are initiated by a homeowner who notices that the solar system is not operating and calls for service. Because every solar system has a fossil or electric backup, a nonattentive owner may not notice that the system is nonoperational or may not care. In these cases, a failed system would be presumed to be operating based on its absence in the service record. The number of these unreported nonoperational systems is not known.

The SWAP data are based on a 2003 field survey of systems that were installed ten years previous. Only systems that were actually inspected are included in the totals. The various rows in the hi level summary datasheet contain the critical related information—the "total installed systems," the "total attempted inspections," the "total actual inspections," the "total operational systems," and the "total non-operational systems." Since the inspection was conducted by experienced solar engineers from FSEC, these data probably present the most accurate representation of the reliability of fielded SHW systems.

The "percent of operational systems" is also listed. One minus this value is the "sample proportion of problems relative to total inspected." Since these percentages are taken from a sample of fielded SHW system (i.e., the ones that were inspected), a logical question is how well might this proportion represent the overall population of systems (i.e., all of the fielded SHW systems in the world). Using the sample size and assuming normal distributions, the 95% confidence limits for the proportion can be interpolated from a table (Crow et al. 1960). There is a 95% confidence that the actual population proportion lies between the upper and lower confidence limits.

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‡‡ As will be discussed later in this report, it is important to note that the exact number of problems is unknown. Thus, the numbers used here represent the best estimates possible based on the available data.

The same confidence limits are presented in the Sacramento hi level worksheet based on the SMUD installation data. Note that the SMUD and SWAP proportions for the various system types are quite different because the databases represent different measures; one is based on service records and the other based on a field survey. More discussion about the confidence limits is found in Section 7.

The HECO hi level worksheet is in a similar format. The number of total installations is unknown. Therefore, the statistical presentation is limited to the basic averages presented in the other hi level worksheets.

6. DISCUSSION OF RELATED AND ANCILLARY STUDIES

This database consists of several sets of reliability data obtained from different sources, as described in Section 2. Some of those sources had previously reported on analyses of the datasets that were procured for this project. The most relevant ones include:

- A report on the Sacramento data analysis by Harrison, published by FSEC;
- A final report on the SWAP program by Harrison, published by FSEC;
- A report on the ASU survey, by Wood et al., published by ASU under contract to NREL; and
- A report on the NREL survey, by Burch, a draft report that was not published.

All of these reports are contained in their entirety in Appendix B.

The Sacramento analysis by Harrison is well done. In it he carefully examines the records from the two contractors (Bergquam and Murray) and compares them. He also discusses each major problem category separately and ranks the problem categories based on reported total service calls.

The report contains tabled values of reported failures and some simple averages. No plots or other statistical analysis are included. The report includes valuable discussions about failures, their potential sources, and frequency. A major conclusion is that valves are the most problematic component in a fielded pumped system.

The SWAP report, also authored by Harrison, is thorough and informative. It reports on the development of the SWAP program and describes its implementation. It contains a detailed summary about how the 2003 field survey was conducted and the findings. It contains high-quality data and is perhaps the best source of SHW reliability data that exists today.

The ASU study, conducted by Wood and his team, is also well done and presents an overview about how the industry survey was conducted, including some of the questions that were posed as part of the survey. While the report does not include raw data or a copy of the survey questions relating the lifetime and reliability measures, it does contain summary statistics including a mean value and standard deviation for each reliability metric. All of the reliability and lifetime estimates are presented in graphical plots. It also contains a list of the open-ended questions that were posed to the industry participants about impediments and other problems in the industry.

It is unclear how the ASU researchers defined the *mean lifetime* metric. As noted by Hiller (2000), *service life* is the most useful metric. It is the time required for 50% of specific fielded systems or components to fail. Since the lifetime metric is not clearly defined, it is assumed that it is the participant's best guess about how long the average systems or components are operational in the field. This estimate is less useful than service life and increases the uncertainty as these data are compared to other survey data.

Conclusions from this study suggest that drain ball valves, horizontal-shaft pumps, and collector enclosures are the most reliable components. The least reliable ones include mixing valves and pipe insulation. In total, the report is credible.

The NREL survey, conducted by Jay Burch, contains a compilation of lifetime estimates for various components. Importantly, these estimates are for service life, as it is normally defined within the reliability engineering community. Details are provided about how the data were collected and analyzed. The report presents service life estimates for a long list of components under best- and worst-case conditions. This report contains perhaps the highest-quality estimates of *service life* for SHW systems and components.

Additionally, the report describes many recommendations and ideas for improving the reliability of SHW systems. Overall the report is well done and the data are considered to be as high a quality as can be expected from this type of survey. Unfortunately, the report was never published.

In total, these four reports constitute the bulk of the existing general information about SHW reliability. These reports, in their entirety, are included in Appendix B, with permission from the authors.

In addition to the studies about overall reliability of SHW systems, substantial work on corrosion in solar collectors was conducted by Menicucci et al. at SNL. This work was initiated by a series of failures of ICS systems at the Tucson, Arizona, subdivision Civano just after the turn of the century. All of the failures were due to pitting copper corrosion. Analyses by SNL's Corrosion Lab and the Copper Development Association suggested that the corrosion event was caused by a unique water quality condition coupled with high operating temperatures that were exacerbated by shallow mounting angles, some lying nearly flat on the roofs.

In addition, Menicucci investigated a catastrophic failure of a large solar pool system that used unglazed copper collectors. Massive amounts of pitting corrosion destroyed the 6,000-square-foot collector within a 72-hour period. The corrosion was induced by radical changes to the chemistry of the pool water that resulted from chemically shocking the pool.

Information about these events and others are contained in Menicucci et al. (2007).

7. COMPARISONS AND ANALYSIS OF DATABASE

This section presents the results from comparing the six datasets that are contained in the database. The datasets can be categorized into two basic groups: (1) counts of problems based on field repairs or field surveys and (2) results of surveys of experts.

The field repair information is contained in the SWAP, Sacramento, and HECO worksheets in the database. The ASU, FSEC, and NREL survey datasets are contained in the appropriately labeled worksheets in the database.

As the reader progresses through the ensuing discussion, it might be useful to have available for reference the database itself. There are numerous references to the database throughout this section. The database is contained in print in Appendix C. It is electronically available at http://www.sandia.gov/Renewable_Energy/excel/Reliability%20database.xls.

Comparison of the Field Data from SWAP, HECO, and Sacramento

The combined dataset, a worksheet labeled "Combo hi level sum," provides a good starting point for the comparison. It contains the summary total problems for all three datasets. Figures 1 through 5 present a graphical breakdown of the problem areas, as a percentage of totals, for all of the major system types.

Valves, sensors, and pumps appear to be the predominant problem among systems that use these components. This is consistent with previous studies.

Pool systems show many collector problems, which may stem from early problems with polymers used in solar pool collectors. These problems are believed to be solved today with advanced polymer design. In the absence of additional information about the pool systems, little more discussion is possible, and solar pool systems will not be addressed further in this report.

A more interesting comparison is between the SWAP and Sacramento datasets (reference worksheets "Sacramento Hi lev sum" and "SWAP Hi lev sum"). Because both of these datasets contain records of similar types for systems that were installed in the 1990s, the failure patterns would be expected to be similar. One difference is that one set of data, Sacramento, is for systems installed in California while SWAP data are for systems installed in Florida. This geographical difference may be expected to be inconsequential because many of the same manufacturers supplied hardware to both locales.

However, Greg Kolb of SNL has suggested that collector failures may be higher in a location where a greater percentage of the pumped systems are of the direct type rather than the indirect type. He theorizes that direct systems, which continually pump fresh domestic water through the collectors, would subject the collector to greater potential corrosion. Thus, collector failures would be greater in this location than in one with a greater percentage of indirect systems. However, since indirect systems contain more total components (in terms of pumps and valves), failures of these components would be higher.

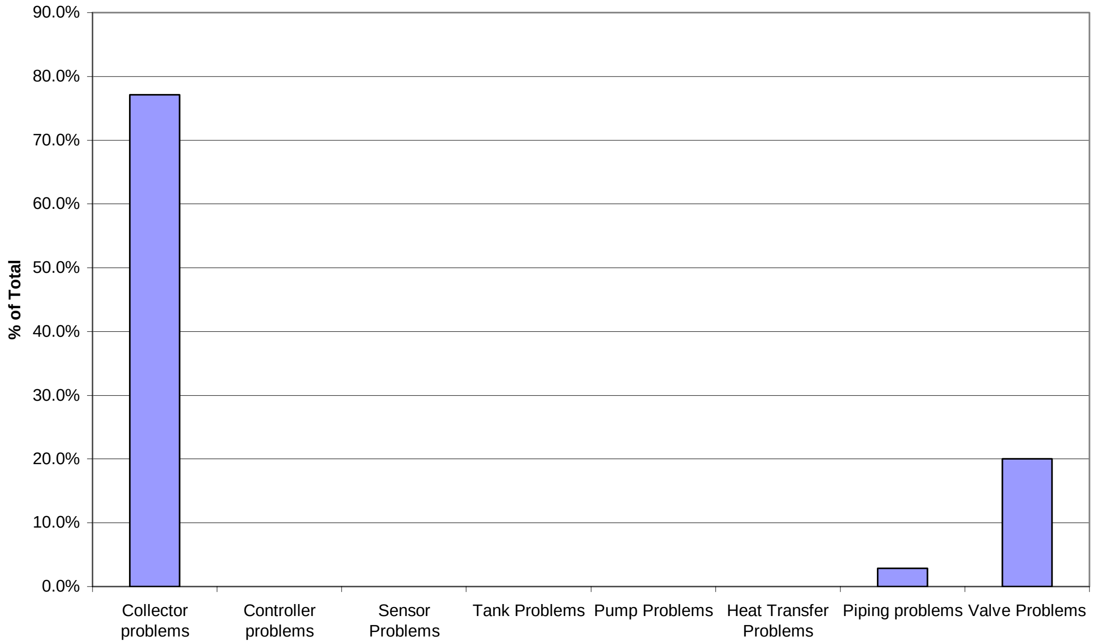

Figure 1. ICS Problems by Category.

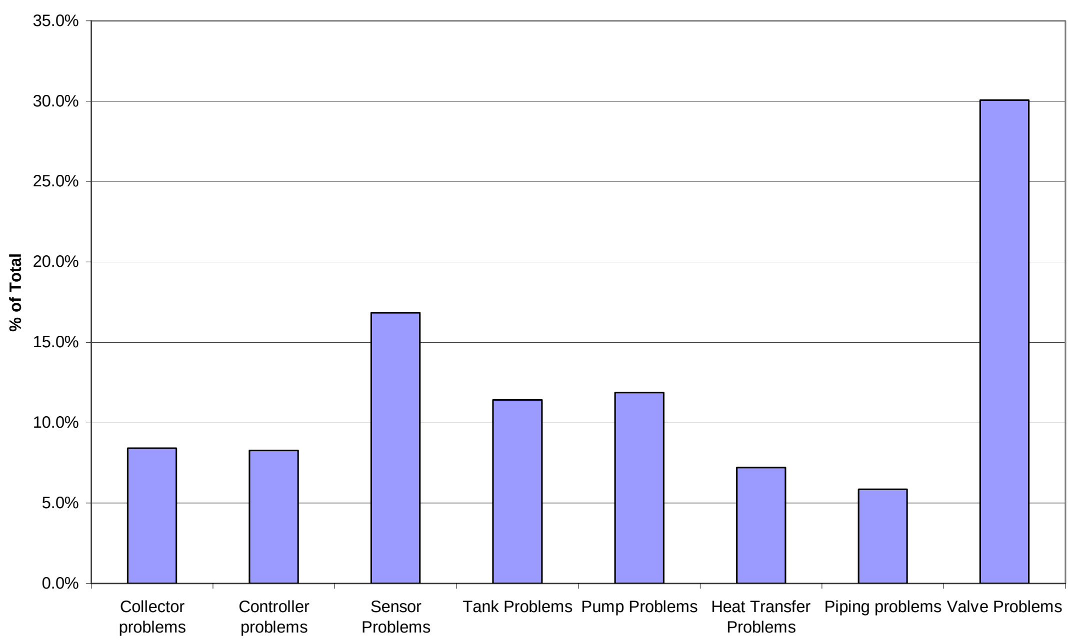

Figure 2. Pumped Systems Problems by Category.

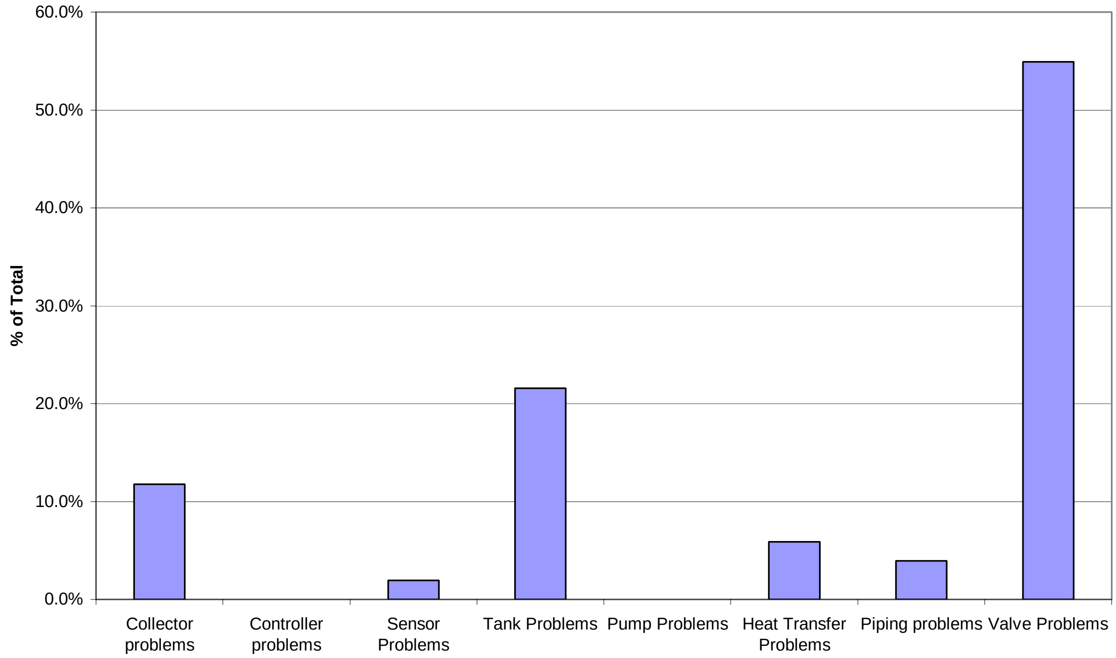

Figure 3. Thermosiphon Problems by Category.

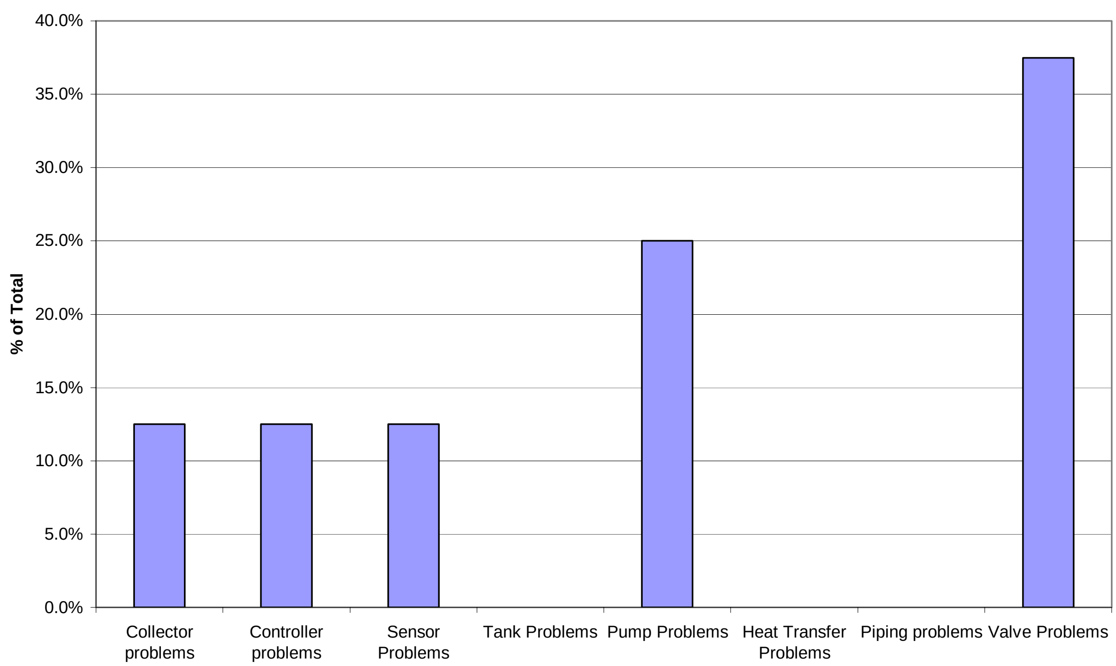

Figure 4. PV-Controlled System Problems by Category.

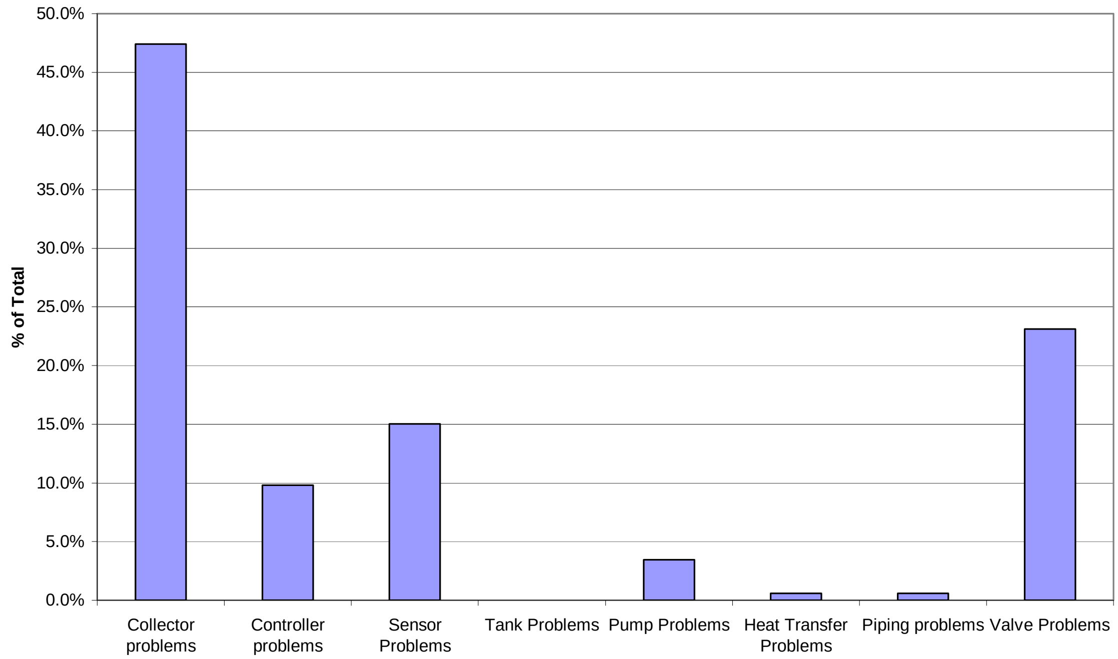

Figure 5. Pool System Problems by Category.

Direct-pumped systems are typically installed in areas of the country that are not subjected to significant freezing. If it can be shown that a large percentage of the SWAP systems were of the direct type and that most of the Sacramento systems were of the indirect type, then the SWAP data would show a higher percentages of collector failures and a lower percentage of other component failures than would be observed in the Sacramento data.

The data do show this trend. About 23% of all pumped system failures among the SWAP systems are due to collector failures, whereas only about 7% of collectors failed among the Sacramento systems (see worksheets "Sacramento Hi lev sum" and "SWAP Hi level sum" in the database).

Unfortunately, the exact details about the type of pumped systems installed in the SWAP program are not known, even among the ones that were surveyed.[§§] Even within the Sacramento systems where the exact system types are known, the service records are not sufficiently clear to distinguish between the types of pumped systems that were being repaired because those details were not always recorded. Thus, although the theory is plausible and the data tend to support it, it remains moot.

[§§] According to John Harrison of the Florida Solar Energy Center, all of the SWAP systems that were installed were either differentially controlled or ICS. However, the exact configuration of these systems is not known with certainty, such as might be contained on a mechanical drawing. More information: http://www.fsec.ucf.edu/en/research/solarthermal/swap/swap_allsites.htm.

Only two system types are common between the SMUD and SWAP datasets, ICS and pumped. Table 1 shows the problem totals for each system type expressed as a percentage of total problems. Figures 6 and 7 show the results of comparing the two summary problem datasets.

Table 1. Comparison of Proportions of Failed Systems

	ICS comparison								
	SWAP (n-=21)				SMUD (n=14)				
Reported problems	Mean proportion	Upper 95%	Lower 95%		Mean proportion	Upper 95%	Lower 95%		Significant Difference
Collector problems	66.7%	83%	51%		92.9%	100%	70%		no
Controller problems	0.0%	0%	0%		0.0%	0%	0%		
Sensor Problems	0.0%	0%	0%		0.0%	0%	0%		
Tank Problems	0.0%	0%	0%		0.0%	0%	0%		
Pump Problems	0.0%	0%	0%		0.0%	0%	0%		
Heat Transfer Problems	0.0%	0%	0%		0.0%	0%	0%		
Piping problems	4.8%	0%	10%		0.0%	0%	0%		no
Valve Problems	28.6%	44%	14%		7.1%	0%	25%		no

	Pumped comparison								
	SWAP (n-=71)				SMUD (n=585)				
Reported problems	Mean proportion	Upper 95%	Lower 95%		Mean proportion	Upper 95%	Lower 95%		Significant Difference
Collector problems	22.5%	36%	10%		6.8%	9%	4%		yes
Controller problems	15.5%	23%	8%		6.2%	9%	4%		no
Sensor Problems	1.4%	6%	0%		19.0%	24%	14%		yes
Tank Problems	2.8%	9%	0%		12.6%	17%	9%		no
Pump Problems	5.6%	12%	1%		12.6%	17%	9%		no
Heat Transfer Problems	0.0%	0%	0%		8.2%	10%	5%		yes
Piping problems	7.0%	15%	2%		5.8%	8%	4%		no
Valve Problems	45.1%	58%	32%		28.7%	36%	23%		no

The ICS system has few moving parts to fail (Figure 6). Therefore, both datasets show the predominate failures to be with the collector itself. Among pumped systems, both datasets show similar trends and indicate that valves are the most problematic component (Figure 7). Collectors and controller problems seem to be more prevalent in the SWAP systems than at SMUD. Conversely, sensor, tank, and pump problems constitute a greater percentage of the problems at SMUD than in SWAP.

Tests were conducted to determine whether the differences between the two datasets are statistically significant. These tests can help determine, at a specific level of statistical significance, whether differences are due to random chance or whether they are likely to be real in the whole population of collector types. Table 1 contains the results of the tests.

The column labeled “Mean Proportion” is the percentage of problems allocated to the specific components listed. The approximate upper and lower 95% confidence limits can be easily computed for each based on a graph (Crow et al. 1960). The confidence limits imply that based on the population size (n), there is a 95% probability that the proportion computed from the population of all of these type of collectors in the field would fall between these upper and lower values. These limits provide an easy and visual method to compare with other proportions computed from different datasets. If there is overlap of the ranges, then it is possible that the proportions may actually be the same in the population and the difference observed here is simply a chance event. Therefore, the difference would not be considered to be significant.

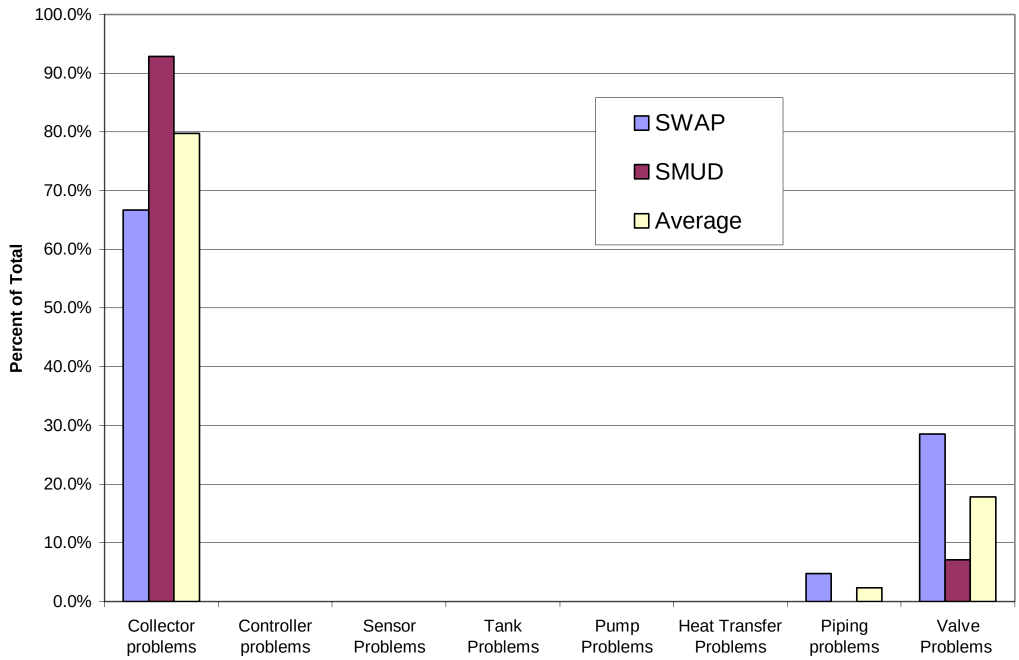

Figure 6. Comparison of ICS Problem Allocation.

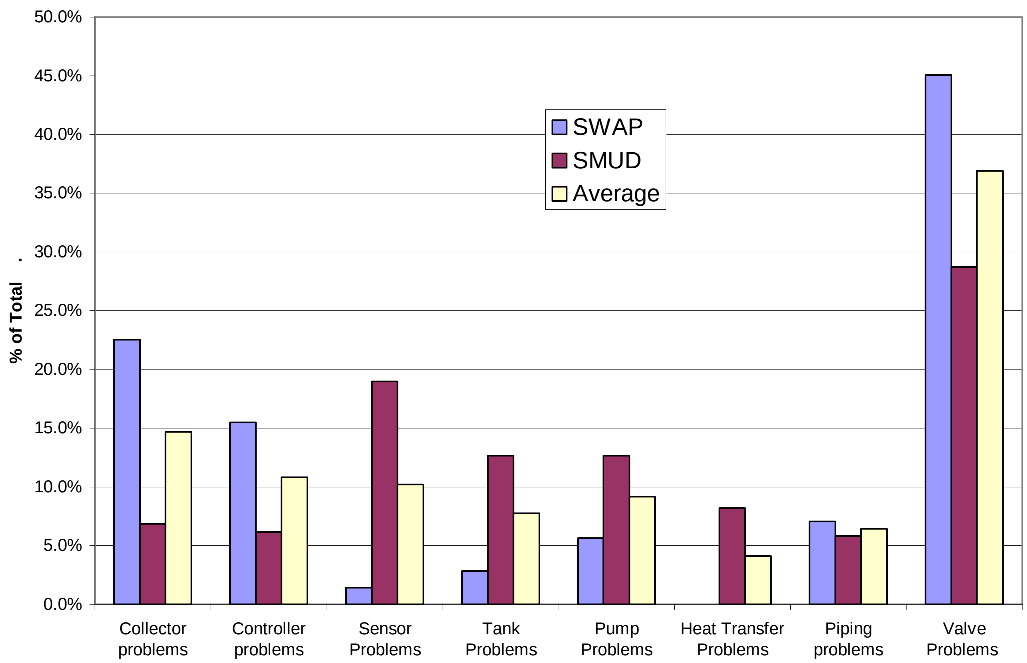

Figure 7. Comparison of Pumped System Problem Allocation.

For example, row one of Table 1 compares the proportion of problems allocated to collector problems for the SWAP and Sacramento datasets. In the SWAP dataset the sample proportion is 66.7% while Sacramento is 92.9%, a difference that appears considerable. However, because of the relatively small sample sizes the approximate 95% confidence bands are large, ranging from 51 – 83% for SWAP and 70 – 100% for SMUD. These ranges overlap, indicating that the difference is not statistically significant because the actual population proportions might be anywhere in the region of 51% to 100%. The sample proportions for each are 66.7% and 92.9%.

The test was applied to each component proportion for both types of systems. The conclusion from the test is found in the last column. As can be seen, the differences between the proportions for the ICS system components measured in the SWAP and SMUD datasets are not significant. Thus, the datasets appear to be consistent and reasonable.

This is not the case for pumped systems. Some of the proportions are significantly different and others are not. In these datasets the pumped system sample size is much larger than for ICS system, resulting in tightened confidence limits. Thus, differences, if they are real, are more likely to appear in the pumped system data. Based on these tests, it appears that these two datasets have significant and real differences.

Another visual method of examining these two datasets is by mapping a sorted list of components based on their proportions. Figure 8 shows the sorted list for pumped system problems. Under the respective captions of "SWAP" and "SMUD" are the problem areas sorted in descending order based on the corresponding proportion values. The arrowed lines connect the matching problem area. If the datasets were consistent, all of the arrows would be a set of horizontal lines. As can be seen, this is not the case and is another indication that these datasets are different, at least with respect to pumped systems.

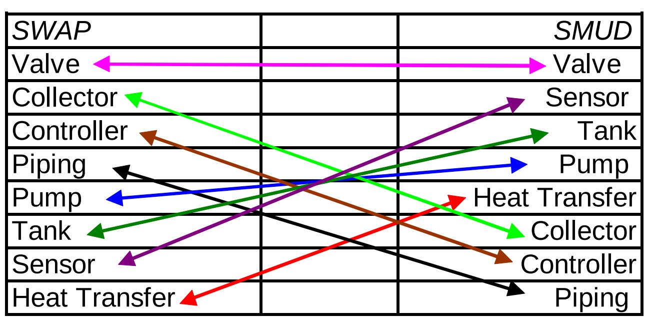

Figure 8. Comparison of Sorted Problem Areas for Pumped Systems.

Another way to compare these two sorted lists for pumped systems is by testing them with the Spearman Rank Correlation method (Spiegel 1961). The method is particularly useful when comparing a set of factors or measures that were derived from different measuring techniques, both of which might be expected to produce a similar or identical rank ordering of those factors. In this case, there are two sets of data that purportedly measure factors of reliability of SHW systems. The factors are the "problem areas" that were identified.

The Spearman test was applied to quantitatively test the ordered lists depicted in Figure 8. The results of the tests are shown in Table 2. The null hypothesis in this case is that there is no significant difference in the rank ordering of the two sets of factors. As can be seen, the resulting Spearman correlation coefficient (r_s) is far lower than the 5% critical value for a two-tailed test. Therefore the hypothesis can be rejected and it is logical to assume that the lists are different.

Table 2. Rank Comparison of Pumped Systems

Rank comparison (pumped systems)			Spearman Test	
Component	***SWAP Rank***	***SMUD Rank***	***Difference***	***Difference^2***
Valve	1	1	0	0
Collector	2	6	4	16
Controller	3	7	4	16
Piping	4	8	4	16
Pump	5	4	-1	1
Tank	6	3	-3	9
Sensor	7	2	-5	25
Heat Transfer	8	5	-3	9
			sum diff^2	92
			r_s	-0.10
			Critical value 5%	0.74

A definitive explanation for the difference is not readily apparent based on the details available in the datasets. However, it is possible that certain system types, such as those with less rugged collectors or other fundamental flaws, might have biased the data

Both of these datasets have information about the number of systems that were installed (see worksheets “Sacramento Hi lev sum” and “SWAP Hi level sum” in the database). As a result, the proportion of total operational systems can be computed based on the samples. As above, the 95% confidence limits can be computed and these can be plotted and compared.

Figure 9 shows a plot of the proportions of nonoperational systems taken from the respective SWAP and SMUD samples. The three values, the lower 95% limit, the sample proportion, and the upper 95% limit are shown as a vertical line. The large dot in the middle of the line is the computed proportion from the database. The lines are color-coded to show the dataset origin. The confidence limits are large for the SWAP data because the sample size is relatively small, at least as compared with SMUD.

As can be seen within the SWAP dataset, the differences between the proportions for the ICS and pumped systems appear to be statistically significant. There are no thermosiphon system data in the SWAP dataset.

Within the SMUD dataset, there appears to be no significant difference between the ICS and thermosiphon system. However, there appears to be a significant difference between these two systems and the pumped systems.

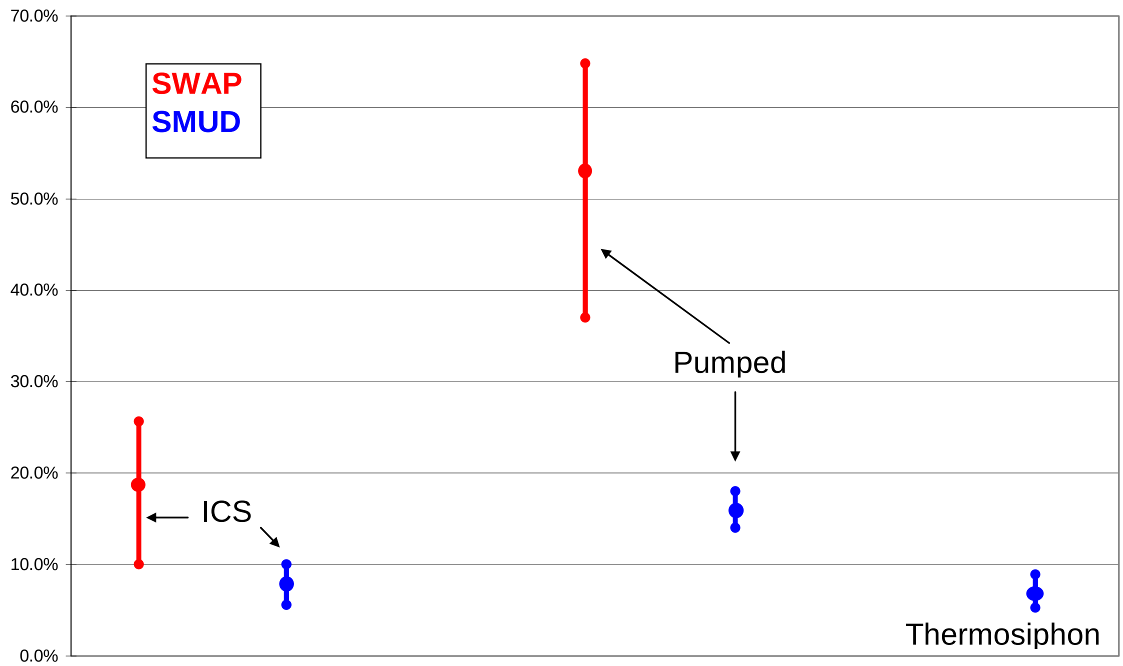

Figure 9. Proportion of Problematic Systems as a Percentage of Total Installed (plus approximate 95% confidence limits).

The results are reasonable and consistent with expectations. Pumped systems have many more components that can potentially fail than do the ICS and thermosiphon systems, which are relatively simple.

The difference between the proportion of nonoperating systems in the SWAP and SMUD datasets is very large and significant. Some of this difference perhaps can be explained in that the SWAP dataset is based on a field survey of systems; thus every non-operational system is recorded in the data. In the SMUD dataset, however, only systems that were identified by their owners as being nonoperational are recorded. It is possible that many nonoperating systems existed in the field and are presumed operational by their absence in the dataset. In any case, it appears that ICS and thermosiphon systems are much more likely to operate problem-free for at least 10 years than pumped systems.

Contrasts with Other Information

In 2005, Ron Richmond, then representing HECO, presented data at the Solar Power 2005 meeting in Washington DC (Richmond 2005). In that presentation he reported that over 27,000 SHW systems had been installed on the Hawaiian Islands. Richmond presented information that suggested warranty claims for these systems totaled to 158. The reporting period for the information was 1996 to 2004, an eight-year span.

Using these data, a failure rate of 0.6% is reported, far lower than what has been found in the SMUD and SWAP data; the SMUD and SWAP failure rates are at between 50 and 90 times higher, respectively. Some of this large disparity could be related to differences in collector types due to geographical conditions, as was discussed above relative to direct and indirect systems at SMUD and SWAP. However, based on information available for this study, it is not possible to reconcile the differences between the HECO report and information derived from the SMUD and SWAP data. It is an item of substantial curiosity and should be investigated further.

Comparison of the ASU, FSEC, and NREL Survey Datasets

Table 3 contains the summarized data from the three surveys. Summary statistics are found in the last three rows. Also included in the right-most column is the average problem allocation proportions from the "Combo hi level sum," which reflects the average proportions from the three field datasets of SWAP, HECO, and SMUD.

Table 3. Summary of Estimates from NREL and ASU Surveys

Component Mean Lifetime Estimates--Overall Averages					
Component areas	**NREL Average Life (years)**	**ASU Average Life (years)**	**FSEC Average Life (years)**	**Average of all Surveys**	**Allocation of problems SMUD SWAP HECO**
Collector	22.5	20.2	26.0	22.9	16.8%
Controller	20.0	13.0	10.1	14.4	6.9%
Sensors	15.0	11.0	no data	13.0	15.0%
Tanks	18.5	10.5	9.7	12.9	11.1%
Pumps	9.5	9.0	10.9	9.8	10.7%
Heat Transfer	3.0	6.0	9.7	6.2	4.6%
Piping	7.0	11.3	20.0	12.8	4.4%
Valves	8.6	6.9	8.2	7.9	30.4%
Average life all components	13.0	11.0	13.5	12.5	
Minimal life all components	3.0	6.0	8.2	6.2	
Maximum life all components	22.5	20.2	26.0	22.9	

Figure 10 presents a plot of the results. There are no data in the FSEC survey relating to sensors.

While there is some consistency, there are some notable differences between the datasets. In the FSEC survey, piping lifetime estimates are much higher than in the others. This is probably due to how the questions were posed and how the results were consolidated. In the FSEC survey, "piping" referred to the piping material itself, which is often made of metal and long-lived. In the ASU and NREL surveys, piping insulation was noted as a separate item. Insulation is relatively short-lived. Both piping material and piping insulation were rolled up into the general category of "piping" in the database.

The other significant differences involve the category of tanks and controllers, both of which are estimated to have much longer lives from the NREL survey than in the other two. It is not clear how to explain these differences, but they are probably related to the problem just noted above.

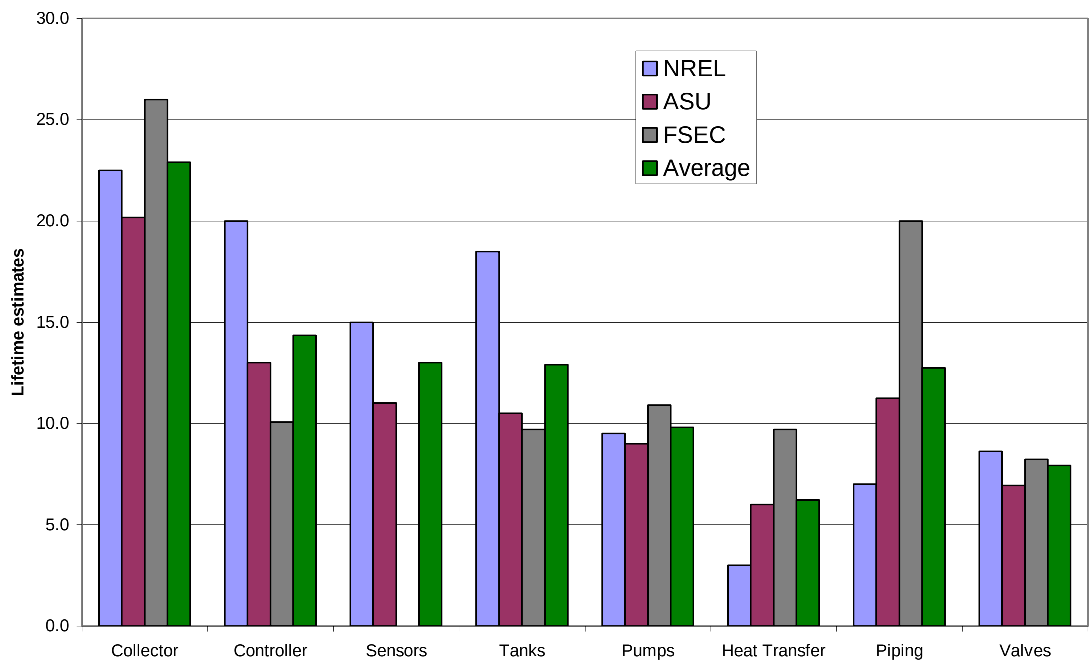

Figure 10. Comparison of Survey Results.

It is important to note that each of these surveys was conducted with a different goal, using different techniques, a different industry representative sample, and different summary methods for the data. Two of the surveys, ASU and FSEC, had limited or no documentation to describe how the surveys were designed and conducted. Therefore, some differences are expected.

The only common statistic among the surveys is the average lifetime, and even that is questionable because it is unclear that all the interviewees were trying to estimate service life, as was clearly the case in the NREL survey. Without statistics about the distribution associated with the means, meaningful parametric tests for statistically significant differences are impossible.

The Spearman Rank Correlation method, a nonparametric test described previously in this report, was applied to test the consistency of the rankings of life estimates between the three sources of data.

From each source (NREL, ASU, and FSEC) the components were ordered according to their estimated lifetimes, as shown in Table 3. Since the FSEC data did not contain a lifetime estimate for sensors, this component was ignored whenever the FSEC data were compared to the other two.

The Spearman test was applied to the three sorted lists, each of which was gathered from a different industry survey source. The null hypothesis is that there is no significant difference between any of the lists. Three tests were conducted, covering every possible comparison among the three lists.

Tables 4a, 4b, and 4c contain the results. The NREL and ASU data sets are the most closely correlated, but the Spearman coefficient (r_s) is equal to the critical value. The other two comparisons show almost no correlation. When the three tests are considered in sum, and given that the NREL-ASU comparison did not technically exceed the critical, two-tailed value, the hypothesis is rejected for all of the datasets. Therefore, it is probable that the three datasets have produced different results.

Table 4. Results of Spearman Test

(a) Rank comparison (NREL v. ASU)			**Spearman Test**	
Component	***Rank (NREL)***	***Rank (ASU)***	***Difference***	***Difference*** ^{2}
Collector	1	1	0	0
Controller	2	2	0	0
Sensors	4	4	0	0
Tanks	3	5	2	4
Pumps	5	6	1	1
Heat Transfer	8	8	0	0
Piping	7	3	-4	16
Valves	6	7	1	1
			Sum Difference^2	22
			r_s	0.74
			Critical value 5%	0.74

(b) Rank comparison (NREL v. FSEC)			**Spearman Test**	
Component	***Rank (NREL)***	***Rank (FSEC)***	***Difference***	***Difference*** ^{2}
Collector	1	1	0	0
Controller	2	4	2	4
Tanks	3	6	3	9
Pumps	4	3	-1	1
Heat Transfer	7	5	-2	4
Piping	6	2	-4	16
Valves	5	7	2	4
			Sum Difference^2	38
			r_s	0.32
			Critical value 5%	0.79

(c) Rank comparison (FSEC v. ASU)			**Spearman Test**	
Component	***Rank (FSEC)***	***Rank (ASU)***	***Difference***	***Difference*** ^{2}
Collector	1	1	0	0
Controller	4	2	-2	4
Tanks	6	4	-2	4
Pumps	3	5	2	4
Heat Transfer	5	7	2	4
Piping	2	3	1	1
Valves	7	6	-1	1
			Sum Difference^2	18
			r_s	0.68
			Critical value 5%	0.79

The ASU survey produced some additional measures other than lifetimes. These are plotted in Figure 11 for information only. There is good consistency among these measures, as expected.

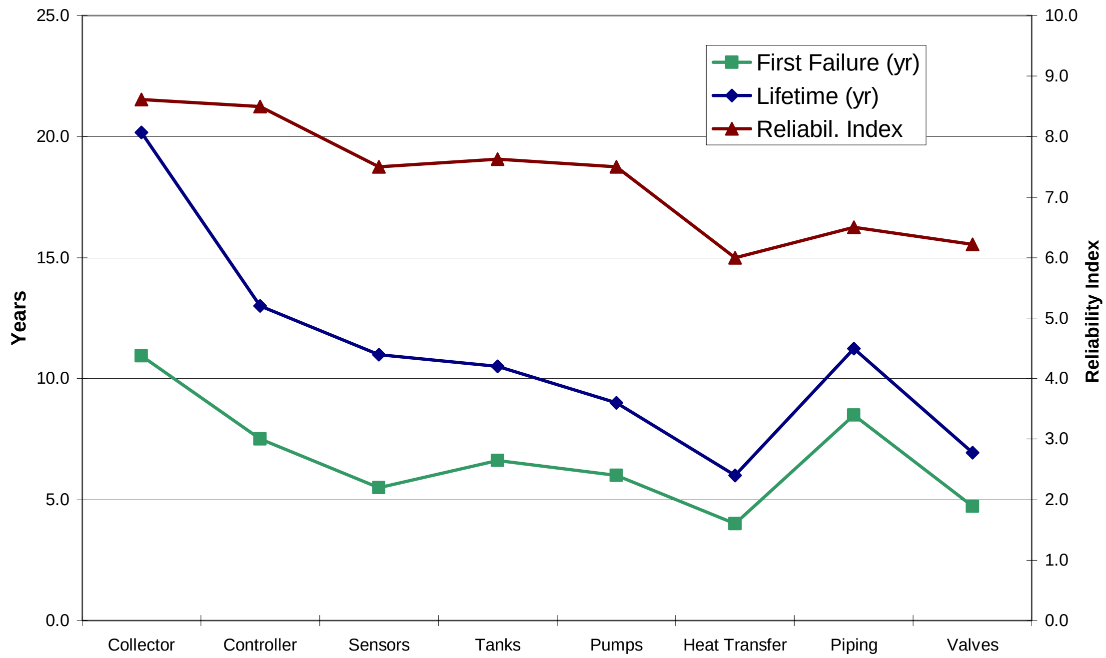

Figure 11. Summary of ASU Estimates.

Comparison of the Survey and Field Datasets

The most interesting comparisons are between the survey datasets (ASU, FSEC, and NREL) and the field datasets (SWAP, HECO, and SMUD). The groups are completely different, one presenting lifetime estimates from industry representatives and the other relating observed problems in the field. Nonetheless, if they are all reflecting the truth about the population of SHW systems in existence, then some consistency should be evident.

It is logical to believe that components with short estimated lives would be the same ones that would create problems in the field. Long lifetimes would tend to be associated with fewer problems.

Figure 12 shows this comparison graphically. On the abscissa is listed the component categories. On the right ordinate is the percent of problems reported (also called the proportion of problems) and has its scale oriented in the normal matter with the lowest value at the bottom and increasing vertically. On the left ordinate is the estimated mean lifetime (red line). Note that it is in reverse orientation, with the largest value at the bottom and descending vertically, because a long lifetime is expected to be inversely related to the number of field problems.

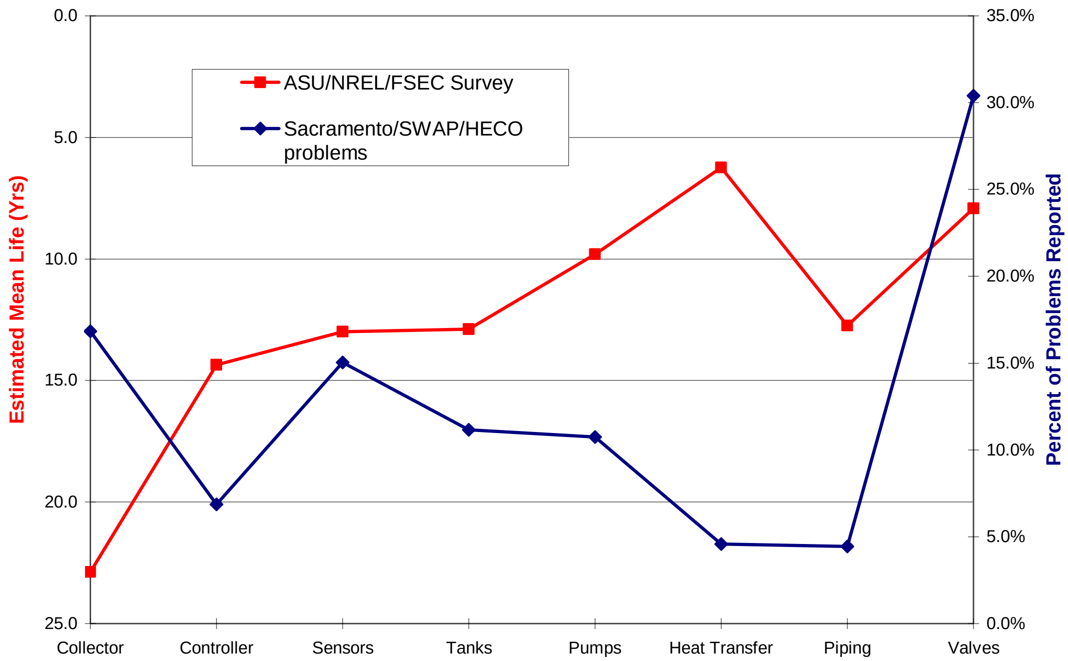

Figure 12. Comparison of Survey Results and Reported Problems.

The plot shows little of the expected consistency. For example, based on the surveys a collector has a long projected life and, therefore, is expected to be less problematic in the field. But this is not what the field data show.

Similarly, pumps, heat transfer, and piping are all inconsistent. The surveys suggest all of these items have short lives, but the field data show them to be relatively nonproblematic in the field. Sensor, tanks, and especially valves show the expected trends.

A way to compare these two basic sets of data is through a visual comparison after sorting, as was done in comparing the pumped systems between the SWAP and Sacramento datasets. Figure 13 shows the results. The survey list in the left-most column was sorted in ascending order according to average lifetime estimates. The field data on the right-most column were sorted in descending order according to the proportion of problems. Except for valves, there is little of the consistency that was expected.

The Spearman test was applied to the two sorted lists shown in Table 5. As can be seen, the Spearman coefficient (r_s) is far below the critical value and the hypothesis that there is no difference between the lists must be rejected. In fact, the coefficient is so low that it is not unreasonable to assume that the difference is largely due to chance, that same kind of variance one might find had the ranks been arranged in a random fashion. In total, these two sets of data appear to be producing different results that lead to different conclusions about component reliability.

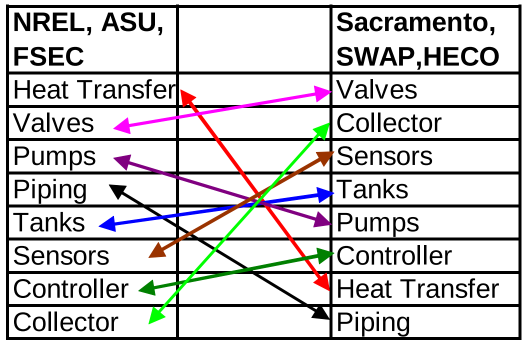

Figure 13. Sorted Comparison.

Table 5. Spearman Test Applied to the Two Sorted Lists

Ranks (Life estimates v. problem allocation)			**Spearman Test**	
Component	***Lifetimes***	***Problem Alloc.***	***Difference***	***Difference^2***
Heat Transfer	1	7	6	36
Valves	2	1	-1	1
Pumps	3	5	2	4
Piping	4	8	4	16
Tanks	5	4	-1	1
Sensors	6	3	-3	9
Controller	7	6	-1	1
Collector	8	2	-6	36
			Sum Difference^2	104
			r_s	-0.24
			Critical Value 5%	0.74

An explanation for these inconsistencies is reduced to speculation. It is possible that the differences in the way that the data were recorded and rolled up have introduced noise and bias into the data. Another possibility is that the estimates are wrong, perhaps for the reason that Hiller suggested (Hiller 2000). Possibly the datasets are sufficiently different that they cannot be combined. If that is true, their value is diminished because it cannot be known which of them is correct.

8. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn from the analysis above:

- There are no known controlled, scientific studies about the reliability of fielded SHW systems. All of the existing data are by-products resulting from existing installations.

- Although the SRCC performs some initial durability tests as part of certification, there exists no long-term testing program for SHW system reliability. It is believed that all collectors in this database received SRCC certification.

- All of the existing data have been measured on systems built in the 1990s. Presuming that systems improve over time, existing systems may be more reliable than what might be suggested by the data.

- The largest dataset of field information is based on Sacramento installations. These data are based on detailed service records. The Sacramento data indicated that about 16% of pumped systems had required service over a ten-year period. Only around 7% of ICS and thermosiphon systems required servicing in that same ten-year period.

- There are two potential biases in the Sacramento data. First, some nonoperational systems may never have been identified for service, so these systems would be incorrectly presumed to be operational based on the absence of a record. Second, a disproportionate number of failures from certain poor-quality systems could indicate more frequent problems than would normally exist.

- The SWAP dataset is of very high quality because the data were based on field inspections of the-year-old systems. The main drawback regarding this dataset is the small sample size.

- The SWAP data showed that over 50% of pumped systems had serious operational problems after ten years; the large majority of them were not operating. Only around 20% of ICS and thermosiphon systems had experienced serious operational problems in the same ten-year period.

- When compared, the SWAP and Sacramento data show a moderate amount of consistency in identifying problematic components. It is possible, but difficult to confirm, that some of the inconsistency is due to differences in how certain components were identified and how the totals were rolled up into the summary worksheets in the database.

- There have been three good-quality surveys of experts to estimate the life and reliability of certain SHW components. All of the studies have potential for bias and error because the estimates are based on human judgments. Only the NREL study confirms that the lifetime estimates reflect "service life," the most desirable statistic for reliability analysis.

- As with the field data, the three surveys show a moderate amount of inconsistency relative to the lifetimes of SHW components. These inconsistencies may relate to differences in how the survey questions were framed and posed and from the process of rolling up the data to the summary worksheets.

- All of the data point to valves as being the most problematic component in a SHW pumped system. In the field datasets, valves are responsible for over a third of the problems.

- Based on the data, solar pool system failures are predominantly related to the collector.

- As expected based on their simplicity, ICS and thermosiphon systems appear to experience the fewest field problems. The difference between the proportion of failures in ICS and thermosiphon systems versus pumped systems is not statistically significant.

- There exists a very significant difference between the proportion of SHW water systems that have failed on the Hawaiian Islands and that same estimate based on SWAP and SMUD data. The Hawaiian failures are much smaller—by factors of 50 to 90 times—than those based on the other datasets. Due to lack of details, no possible explanation can be formulated.

- There is notable discontinuity between the summaries of the field data and the survey data. Admittedly, it is difficult and risky to compare these two very different types of data, one of which contains lifetime estimates and the other that contains records of field failures. However, even with that uncertainty, it is reasonable to expect that components that have short lifetime estimates would fail more frequently in the field. This is apparently not the case based on the database data.

  Each dataset is based on a unique set of assumptions and measures. It is possible that the differences between them create sufficiently large variance so that a meaningful comparison is not possible.

Based on this study, the following are recommended.

1. The DOE, in cooperation with the SRCC (including its test labs) and the national labs, should design and implement a study of SHW reliability based on fielded systems. Most importantly, the study should compute service life (as classically defined) so that specific recommendations can be formed to clearly identify problematic components and to suggest improvements. MTBF values should be computed for all major components so that installers will have sound information to base selections about components and in determining warranty periods.

This study should be designed based on stratified sampling principles and sample sizes should be sufficiently large to produce statistics that are generally representative of the population. The samples should include a sufficient random selection of various system types located in various geographical locations across the United States. Stratified sampling involves ensuring that component subcategories are represented in the data. For example, in the general category of "valve," a "ball valve" is a subcategory, as is a "gate valve."

Field surveys of operating systems, such as was done in the SWAP program, is a good way to collect the required data. These surveys could periodically review the status of a sample of systems throughout the country. If properly designed, the data could produce information that would be useful to provide beneficial information. The field survey program should also include some careful studies that will follow a sampling of fielded systems during their entire life cycle—installation to failure.

All surveys should seek out and carefully record the history of each of the systems that is examined as well as the age of failed components.

The resulting report should be widely disseminated.

2. After the field study is completed and there exists some understanding of failure rates/mechanisms for components along with theories for failures, an accelerated testing program of existing product should commence, starting with the components with highest failure rates. This testing could be done through a collaborative effort between DOE, the national labs, and SRCC.

   Accelerated testing is well established in the industry, especially among automobile and appliance manufacturers. These tests involve rapid repetition of a condition that the tested article will experience more slowly over its life. In a solar collector, this might involve rapidly cycling of pumps and valves and subjecting them to quickly changing environmental conditions, especially heat and cold. Other similar tests can be configured for other components.

   After components fail during an accelerated test, a root-cause analysis should be conducted to determine cause and recommend improvements. SNL is particularly adept at this kind of analysis due to its experience with weapon systems. However, additional expertise could be provided by NREL and some universities. The resulting information should be disseminated to component manufacturers and solar manufacturers and installers.

3. Solar systems with pumps, valves, and controls are expected to fail one or more times during their >20-year lifetime and it is unrealistic to attempt to develop active solar systems that never fail. However, as pointed out in the discussion, the solar-system owner will often not know the system has failed. Simple and inexpensive methods for alerting the owner of nonoperation should be a feature of future residential SHW systems. For example, for an indirect system with a solar storage tank, a simple audible alarm could be issued after the solar tank has been cold for a week. Such alarms would reduce the system down time and could greatly increase the system availability.[***]

[***] Since Availability = Mean Time Between Failure/(Mean Time Between Failure + Mean Down Time), the shorter the Mean Down Time, the higher the availability. To increase system availability, both Mean Time Between Failure and Mean Down Time must be addressed.

4. This report has shown the limited usefulness of reliability data derived from indirect measures, such as repair records. In the future, these indirect measures could be more useful by simply implementing some quality control as they are being collected. For example, the inclusion of the system description in the repair record would be easy to obtain and helpful when used in a reliability analysis. Consistency is also a positive feature to improve data usefulness.

APPENDIX A. References, Bibliography, and Consultants

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Technical Consultants

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- Jeff Currey, Lakeland Electric
- Les Nelson, SRCC
- Byron Winn, Colorado State University
- Jim Bergquam, Bergquam Energy Systems and California State University at Sacramento

APPENDIX B. Copy of Reports

Final Report Part I

DURABILITY & RELIABILITY OF SOLAR DOMESTIC HOT WATER HEATERS
Survey Results

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United States Department Of Energy
Under Cooperative Agreement
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March 1998

PREFACE

This report was prepared by Arizona State University (ASU) as an account of work sponsored by the U.S. Department of Energy (DOE). The results and conclusions contained in this report are those of the authors, and they in no way reflect the opinions of the United States Department of Energy or of any other U.S. Government agency.

Dr. Jay Burch, NREL, was the project monitor. His guidance and assistance is gratefully acknowledged by the project team. Also, the contributions of Deborah Shaver, ASU and Mary Murphy, University of Nevada, Reno are gratefully acknowledged by the project team

This report is the result of the cooperative effort of the following contributors:

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- Kent Whitfield, Arizona State University
- Jing Song, University of Nevada, Reno
- Liang-Jun Ji, Arizona State University
- Betty Hicks, University of Nevada, Reno
- David S.C. Chau, Arizona State University

SUMMARY

Opinions from 28 professionals, service contractors, and installers of solar domestic water heating (SDWH) systems about the reliability of SDWH system components were obtained via a comprehensive survey and follow-up interview. All individuals that participated in the survey have had significant field experience.

This report summarizes the survey results and provides a list of issues and their relative importance.

The system components were divided into two general categories:

1. Pumps, and plumbing fittings
2. Collectors, temperature sensors, tanks, pipe insulation and heat transfer fluid.

The major conclusions were:

- The mean lifetime for pumps and plumbing fittings was almost half of that for the collectors, temperature sensors, tanks, pipe insulation and heat transfer fluid.
- The most reliable components were drain ball valve, horizontal shaft pump, glass cover and collector enclosure.
- The least reliable components were mixing/tempering valve and untreated pipe insulation.
- High system cost and bad experience with solar systems were identified as the most significant problems facing the SDWH industry.
- Improper installation was identified as the largest factor contributing to the relatively high maintenance cost of the SDWH systems.

Table of Contents

1. INTRODUCTION

A) Purpose of survey

An unresolved barrier for consumer acceptance of SDWH systems is the perception than they are unreliable and that their service life is significantly less than that claimed by the manufactures/dealers.

A comprehensive survey was developed to identify and define the relevant durability and reliability issues that affect the long term performance of SDWH systems. The survey was directed towards installers and service contractors with significant field experience.

B) How the survey was accomplished

Initially the survey was sent to more than 300 companies with negligible response. The survey was then refined and modified. The second survey was directed towards selected companies in several geographic areas. A member of the research team made a personal visit to each respondent to pickup the completed survey and to clarify any questions regarding it.

C) Geographical areas serviced by survey participants

Phoenix, AZ

Los Angeles, CA

Sacramento, CA

Reno, NV

Eugene, OR

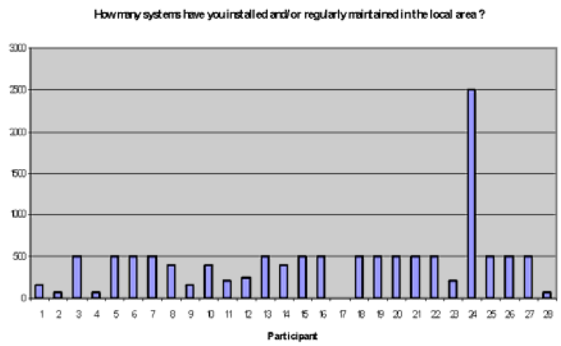
2. SURVEY PARTICIPANTS

A) Experience Level

0. Not answered
1. Closed loop
2. Closed loop (drain back)
3. Closed loop (antifreeze)
4. Open loop
5. Open loop (drain Back)
6. Open loop (recirculation)
7. Thermosyphon
8. ICS
9. Swimming Pool Systems
10. Distributor only

Participant No.	Experience
1	3,4,5
2	0
3	3,4,6,7,8
4	2,3
5	1,2,7
6	2,3,4,7,8
7	1,2,9
8	7
9	1,2,7,8
10	1,2,9
11	0
12	0
13	3,4,6,7,8
14	0
15	2
16	7
17	10
18	1,2,7,8
19	0
20	1,2,7
21	1,2,7,8
22	2,7
23	0
24	0
25	1,2,4,7
26	4,5,7
27	1,7
28	0

B) Number of Systems Installed and/or Maintained



C) GEOGRAPHICAL DISTRIBUTION

Participant	Region
1,2	1-Reno
3,4,5,6,7,8	2-Phoenix
9,10,11,12,13,14	3-Sacramento
15,16,17,18,19,20,21,22,23,24	4-Los Angeles
25,26,27,28	5-Eugene

3. SURVEY RESULTS

A) First group of components (Pumps, and plumbing fittings)

B) Second group of components (Collectors, temperature sensors, tanks, pipe insulation and heat transfer fluid)

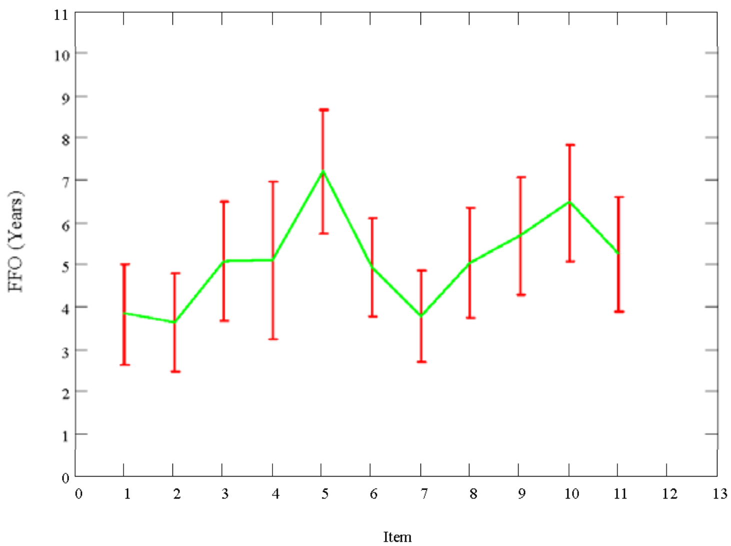
C) General questions and responses

Note.- The vertical lines in the plots correspond to the value of the standard deviation.
Participants who have answered out of range (0 - 10) about the reliability index were not counted.

Durability and Reliability of Solar Domestic

Hot Water Systems
First Group of Components

First Failures Occur (FFO)



mean(FFO) = 5.1 years

The Items analysed are:

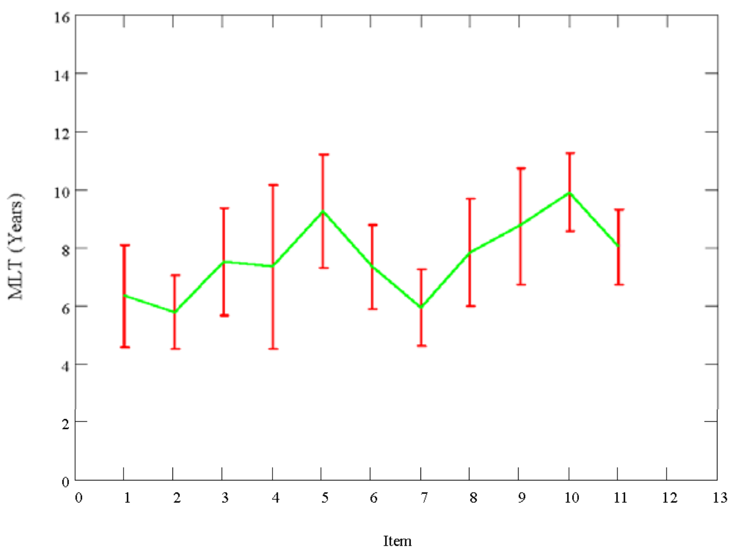
1.- Air Vents
2.- Draindown Valve
3.- Spring Check Valve
4.- Flapper Check Valve
5.- Drain Ball Valve
6.- Vent Valve
7.- Mixing/Tempering Valve
8.- P-T Relief Valve
9.- Pressure Relief Valve
10.- Horizontal Shaft Pump
11.- Vertical Shaft Pump

5

Durability and Reliability of Solar Domestic Hot Water Systems

First Group of Components

Mean Lifetime (MLT)



mean(MLT) = 7.7 years

The Items analysed are:

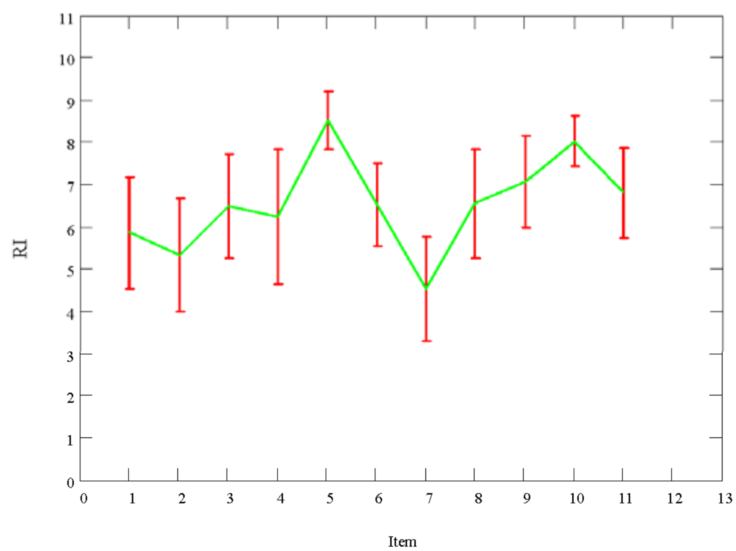
1.- Air Vents
2.- Draindown Valve
3.- Spring Check Valve
4.- Flapper Check Valve
5.- Drain Ball Valve
6.- Vent Valve
7.- Mixing/Tempering Valve
8.- P-T Relief Valve
9.- Pressure Relief Valve
10.- Horizontal Shaft Pump
11.- Vertical Shaft Pump

6

Durability and Reliability of Solar Domestic Hot Water Systems

First Group of Components

Reliability Index (RI), from 0 to 10



mean(RI) = 6.6

The Items analysed are:

1.- Air Vents
2.- Draindown Valve
3.- Spring Check Valve
4.- Flapper Check Valve
5.- Drain Ball Valve
6.- Vent Valve
7.- Mixing/Tempering Valve
8.- P-T Relief Valve
9.- Pressure Relief Valve
10.- Horizontal Shaft Pump
11.- Vertical Shaft Pump

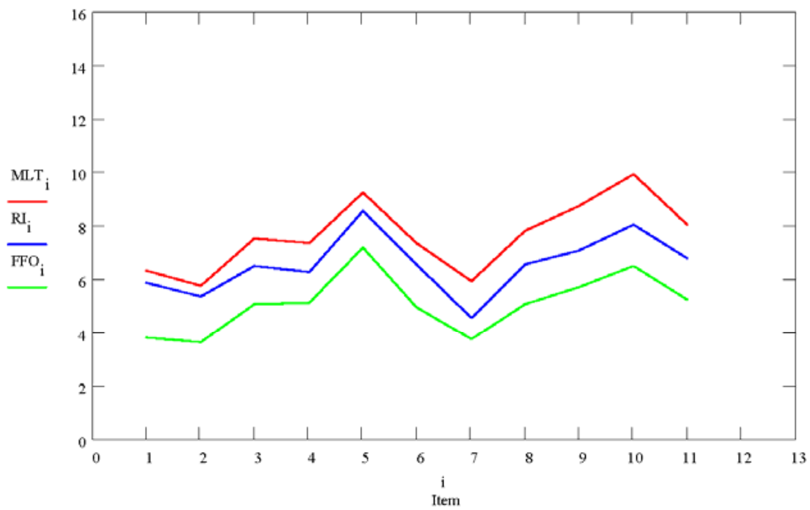
7

Durability and Reliability of Solar Domestic Hot Water Systems
First Group of Components

FFO = First Failures Occur (years)

MLT = Mean Lifetime (years)

RI = Reliability Index (from 0 to 10)



mean(FFO) = 5.1   mean(MLT) = 7.7   mean(RI) = 6.6

The Items analysed are:

1.- Air Vents
2.- Draindown Valve
3.- Spring Check Valve
4.- Flapper Check Valve
5.- Drain Ball Valve
6.- Vent Valve
7.- Mixing/Tempering Valve
8.- P-T Relief Valve
9.- Pressure Relief Valve
10.- Horizontal Shaft Pump
11.- Vertical Shaft Pump

8

Durability and Reliability of Solar Domestic Hot Water Systems

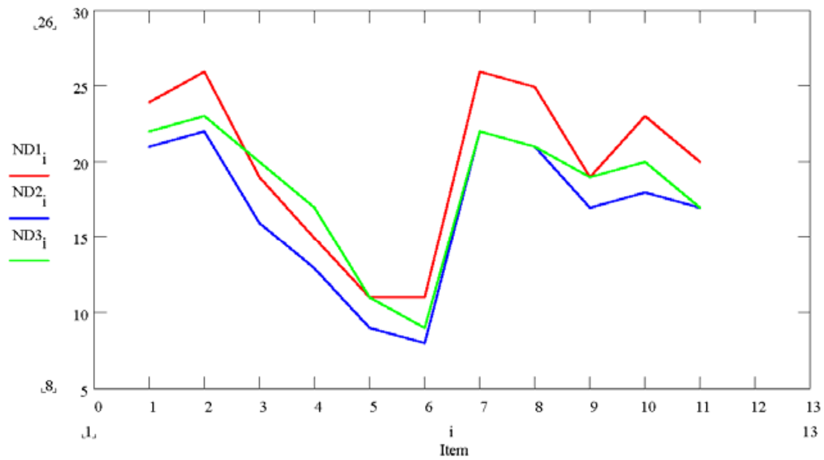
First Group of Components

Number of Participants

ND1 = Number of Participants in "First Failures Occur"

ND2 = Number of Participants in "Mean Lifetime"

ND3 = Number of Participants in "Reliability Index"



The Items "i" analysed are:

1.- Air Vents
2.- Draindown Valve
3.- Spring Check Valve
4.- Flapper Check Valve
5.- Drain Ball Valve
6.- Vent Valve
7.- Mixing/Tempering Valve
8.- P-T Relief Valve
9.- Pressure Relief Valve
10.- Horizontal Shaft Pump
11.- Vertical Shaft Pump

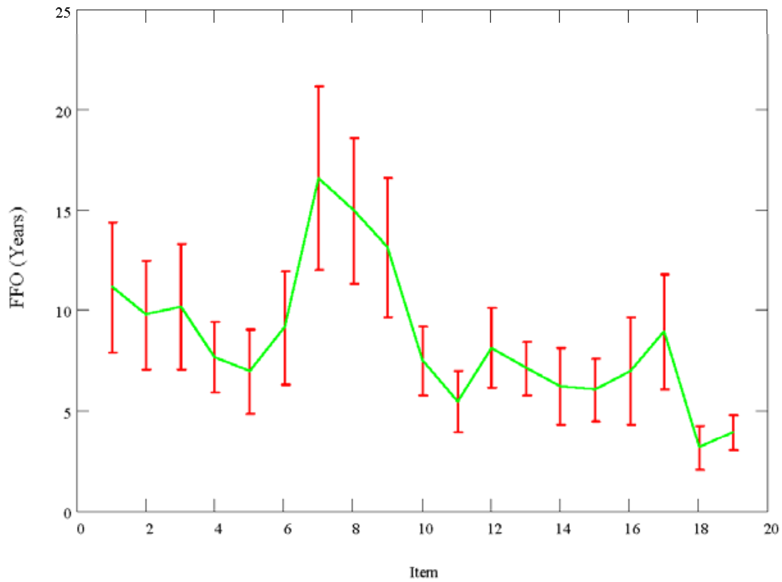
9

Durability and Reliability of Solar Domestic

Hot Water Systems

Second Group of Components

First Failures Occur (FFO)



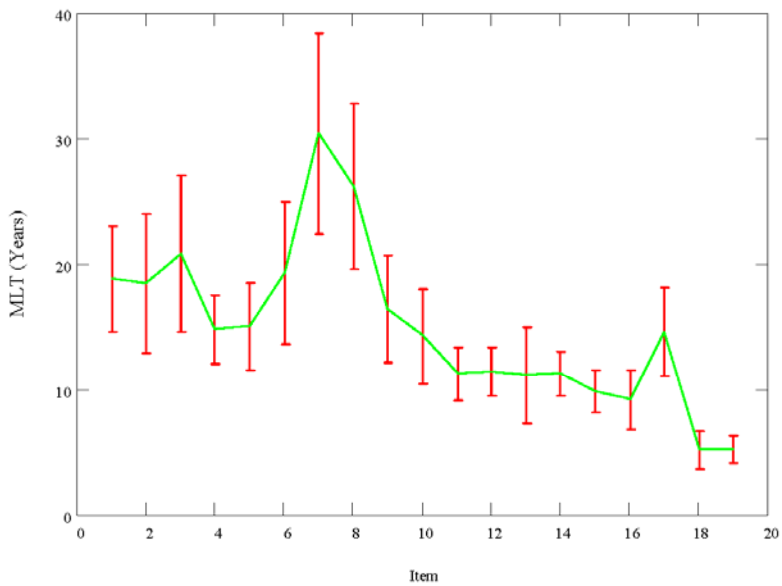
mean(FFO) = 8.6 years

The Items analysed are:

1.- Collector (Passage blockage)
2.- Collector (Cu abs. painted)
3.- Collector (Cu abs. selective)
4.- Collector (Al abs. painted)
5.- Collector (Al abs. selective)
6.- Collector (Fluid passages)
7.- Collector (Glass cover)
8.- Collector (Enclosure)
9.- Collector (Gaskets)
10.- Controllers
11.- Temp. sensors
12.- Storage Tank (Glass lined)
13.- Storage Tank (Steel)
14.- Storage Tank (Thermostat)
15.- Expansion Tank
16.- Pipe Ins. (Painted)
17.- Pipe Ins. (Al Tape)
18.- Pipe Ins. (Untreated)
19.- Glycol Fluid

Durability and Reliability of Solar Domestic Hot Water Systems
Second Group of Components

Mean Lifetime (MLT)



mean(MLT) = 15 years

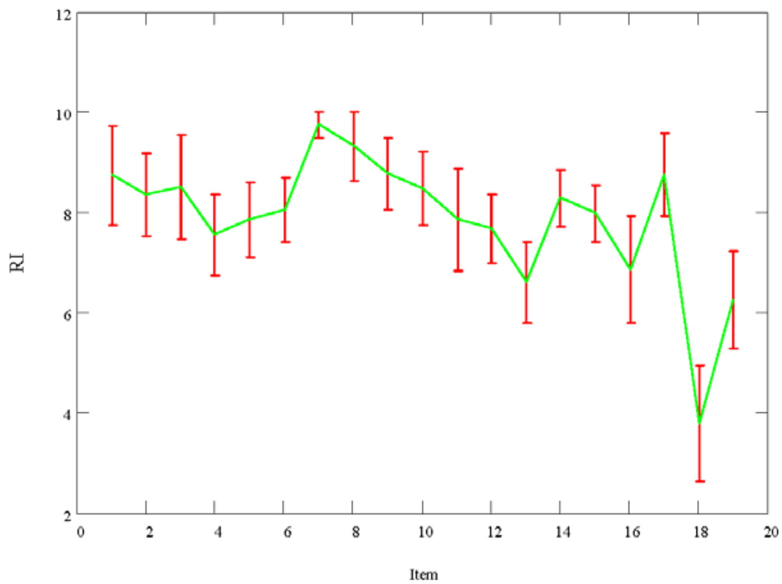
The Items analysed are:

1.- Collector (Passage blockage)
2.- Collector (Cu abs. painted)
3.- Collector (Cu abs. selective)
4.- Collector (Al abs. painted)
5.- Collector (Al abs. selective)
6.- Collector (Fluid passages)
7.- Collector (Glass cover)
8.- Collector (Enclosure)
9.- Collector (Gaskets)
10.- Controllers
11.- Temp. sensors
12.- Storage Tank (Glass lined)
13.- Storage Tank (Steel)
14.- Storage Tank (Thermostat)
15.- Expansion Tank
16.- Pipe Ins. (Painted)
17.- Pipe Ins. (Al Tape)
18.- Pipe Ins. (Untreated)
19.- Glycol Fluid

11

Durability and Reliability of Solar Domestic Hot Water Systems
Second Group of Components

Reliability Index (RI), from 0 to 10



mean(RI) = 7.9

The Items analysed are:

1.- Collector (Passage blockage)
2.- Collector (Cu abs. painted)
3.- Collector (Cu abs. selective)
4.- Collector (Al abs. painted)
5.- Collector (Al abs. selective)
6.- Collector (Fluid passages)
7.- Collector (Glass cover)
8.- Collector (Enclosure)
9.- Collector (Gaskets)
10.- Controllers
11.- Temp. sensors
12.- Storage Tank (Glass lined)
13.- Storage Tank (Steel)
14.- Storage Tank (Thermostat)
15.- Expansion Tank
16.- Pipe Ins. (Painted)
17.- Pipe Ins. (Al Tape)
18.- Pipe Ins. (Untreated)
19.- Glycol Fluid

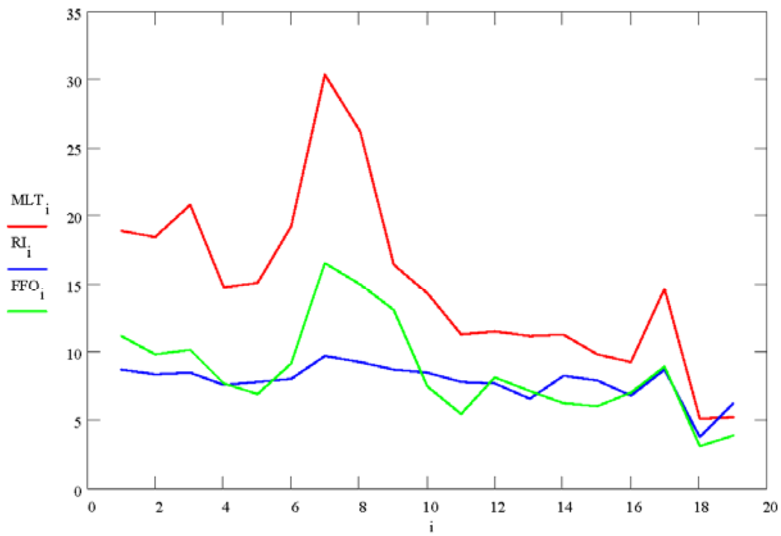
12

Durability and Reliability of Solar Domestic Hot Water Systems
Second Group of Components

FFO = First Failures Occur (years)

MLT = Mean Lifetime (years)

RI = Reliability Index (from 0 to 10)



mean(FFO) = 8.6 years   mean(MLT) = 15 years   mean(RI) = 7.9

The Items "i" analysed are:

1.- Collector (Passage blockage)
2.- Collector (Cu abs. painted)
3.- Collector (Cu abs. selective)
4.- Collector (Al abs. painted)
5.- Collector (Al abs. selective)
6.- Collector (Fluid passages)
7.- Collector (Glass cover)
8.- Collector (Enclosure)
9.- Collector (Gaskets)
10.- Controllers
11.- Temp. sensors
12.- Storage Tank (Glass lined)
13.- Storage Tank (Steel)
14.- Storage Tank (Thermostat)
15.- Expansion Tank
16.- Pipe Ins. (Painted)
17.- Pipe Ins. (Al Tape)
18.- Pipe Ins. (Untreated)
19.- Glycol Fluid

13

Durability and Reliability of Solar Domestic Hot Water Systems
Second Group of Components

Number of Participants

FFO = First Failures Occur (years)

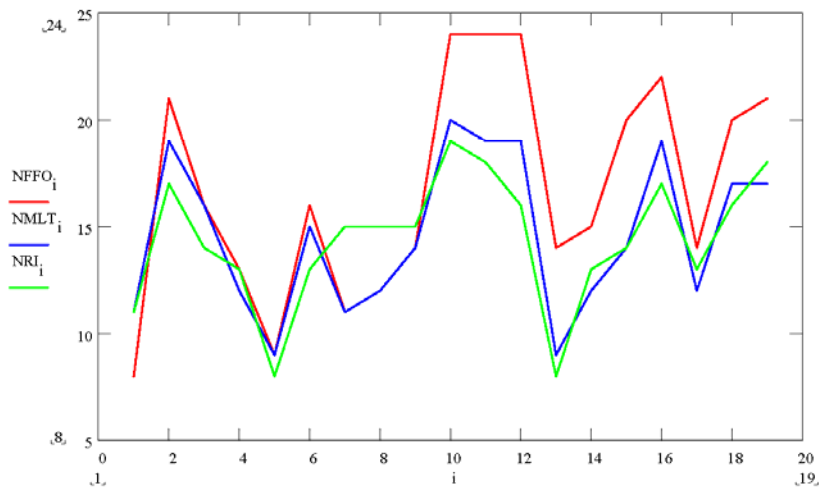
MLT = Mean Lifetime (years)

RI = Reliability Index (from 0 to 10)

NFFO = Number of Participants in FFO

NMLT = Number of Participants in MLT

NRI = Number of Participants in RI



The Items "i" analysed are:

1.- Collector (Passage blockage)
2.- Collector (Cu abs. painted)
3.- Collector (Cu abs. selective)
4.- Collector (Al abs. painted)
5.- Collector (Al abs. selective)
6.- Collector (Fluid passages)
7.- Collector (Glass cover)
8.- Collector (Enclosure)
9.- Collector (Gaskets)
10.- Controllers
11.- Temp. sensors
12.- Storage Tank (Glass lined)
13.- Storage Tank (Steel)
14.- Storage Tank (Thermostat)
15.- Expansion Tank
16.- Pipe Ins. (Painted)
17.- Pipe Ins. (Al Tape)
18.- Pipe Ins. (Untreated)
19.- Glycol Fluid

14

C) Open Ended Question Responses

The survey included several opinion questions that had no choices and no guidance for the answers. All similar answers were grouped together. The percent of respondents that gave similar answers is indicated.

What is the biggest problem facing the Solar Water Heating Industry today?

Number of Participants = 20

1. High investment and long pay back period	75 % *
2. Bad experience with solar systems	60 %
3. Low cost of natural gas	30 %

What factors seem to cause the most maintenance problems with the Solar Water Heating Systems ?

Number of Participants = 25

1. Improper installation	57 %
2. Bad water quality	52 %
3. Lack of regular maintenance	44 %

* Percent of the participants who have identified this situation as the answer.

What are the biggest maintenance problems you most often find with open loop systems?

Number of Participants = 25

1. Valves/Air vent	92% *
2. Control/Sensor	48 %
3. Pump	48 %
4. Freezing	36 %
5. Tank	20 %

What are the biggest maintenance problems you most often find with ICS systems?

Number of Participants = 21

1. Valves/Air vent	62%
2. Glazing	43 %
3. Tank	33 %
4. Collector	19 %
5. Freezing	14 %

* Percent of the participants who have identified this situation as the answer.

16

What are the biggest maintenance problems you most often find with Closed Loop systems?

Number of Participants = 22

1. Glycol	73 % *
2. Control/Sensor	41 %
3. Pump	32 %
4. Expansion tank	27 %
5. Valves/Air vent	23 %
6. Tank	18 %

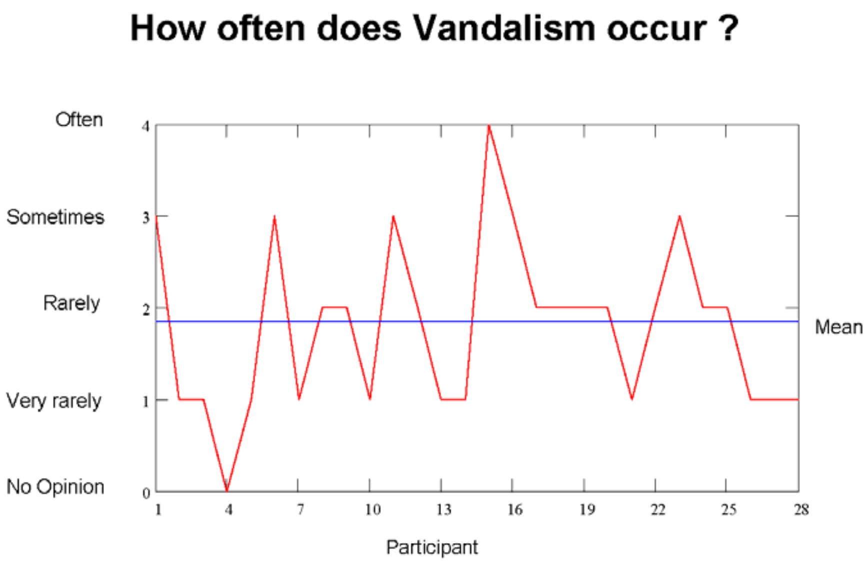
What are the biggest maintenance problems you most often find with Thermosyphon systems?

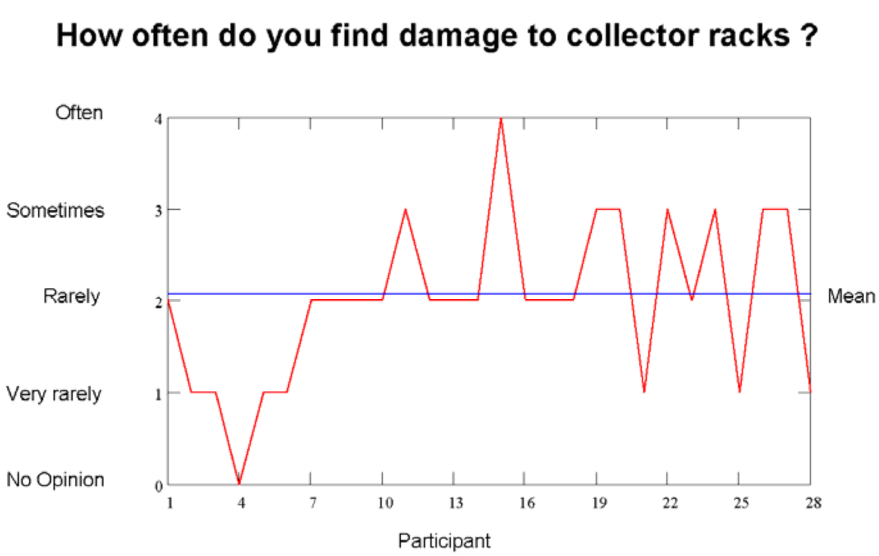
Number of Participants = 23

1. Freezing	56 %
2. Valves/Air vent	52 %
3. Corrosion	30 %
4. Tank	30 %
5. Overheating	26 %
6. Heating element	22 %

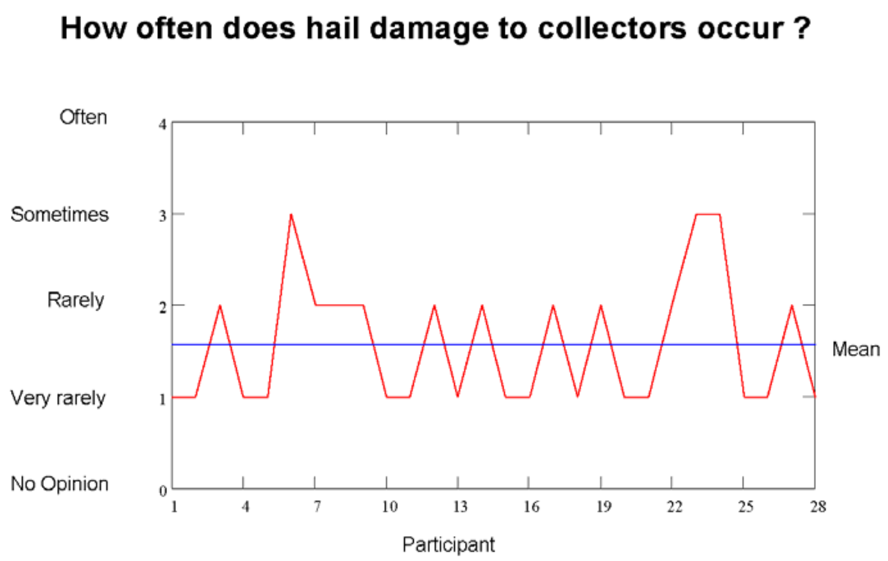
* Percent of the participants who have identified this situation as the answer.

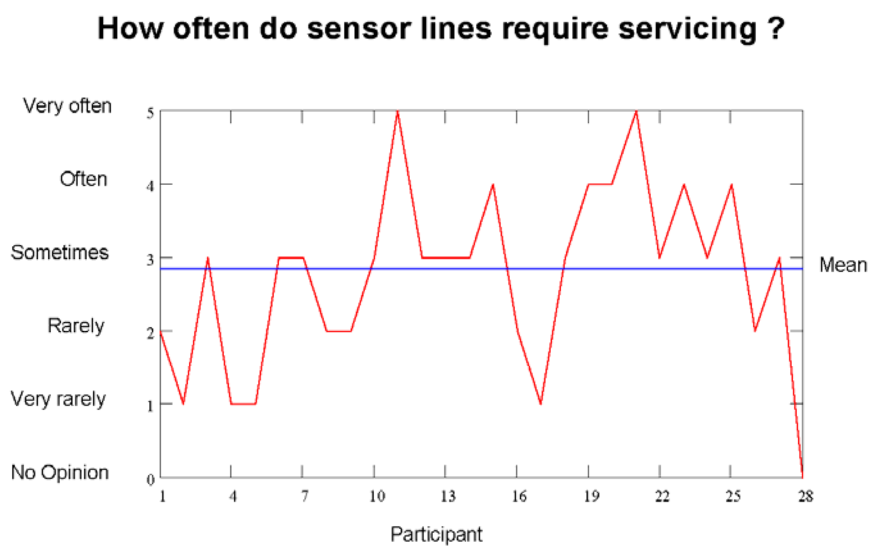
D) Other General Questions





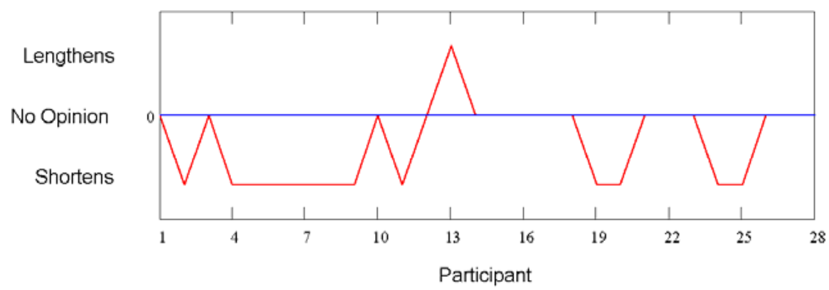
18


How often does hail damage to collectors occur ?
Often
Sometimes
Rarely
Very rarely
No Opinion
0
1
2
3
4
1
4
7
10
13
16
19
22
25
28
Participant
Mean

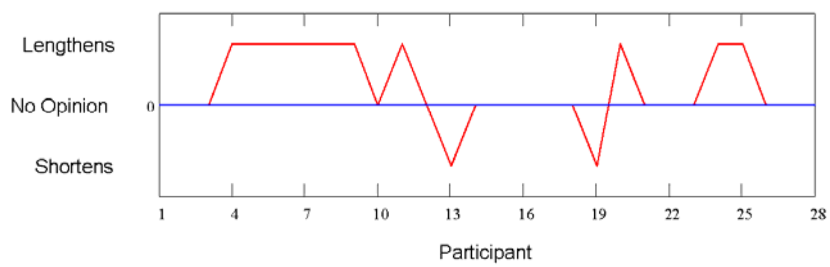

How often do sensor lines require servicing ?
Very often
Often
Sometimes
Rarely
Very rarely
No Opinion
0
1
2
3
4
5
1
4
7
10
13
16
19
22
25
28
Participant
Mean

19

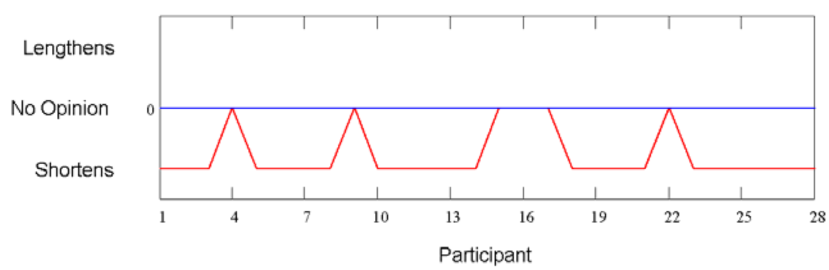
Do you believe that a shallow collector angle lengthens or shortens the lifetime of the Solar Water Heating System?



Do you believe that a latitude or larger collector angle lengthens or shortens the lifetime of the Solar Water Heating System?

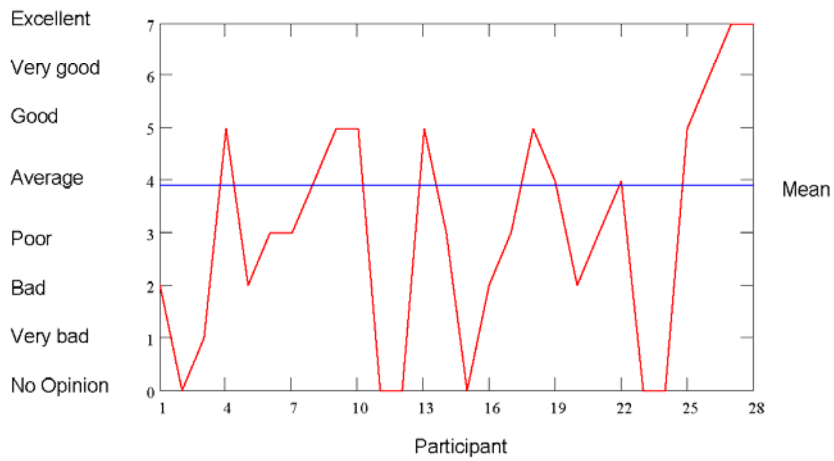


Do you believe that a collector oversizing lengthens or shortens the lifetime of the Solar Water Heating System?



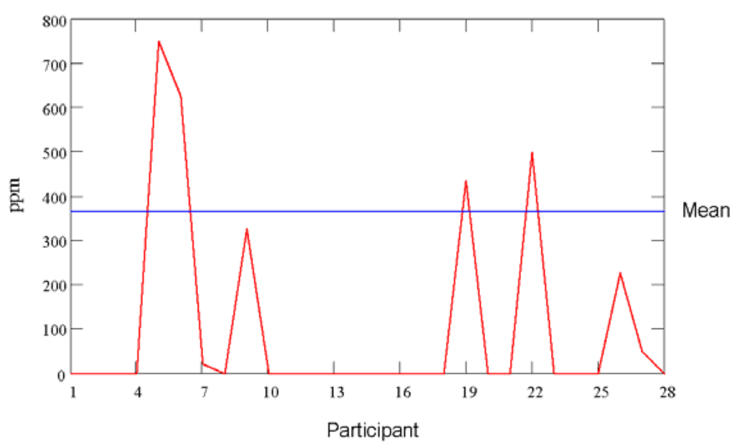
What is the Water quality in your service area?

Number of participants = 22



Have you measured total dissolved solids for your service area?

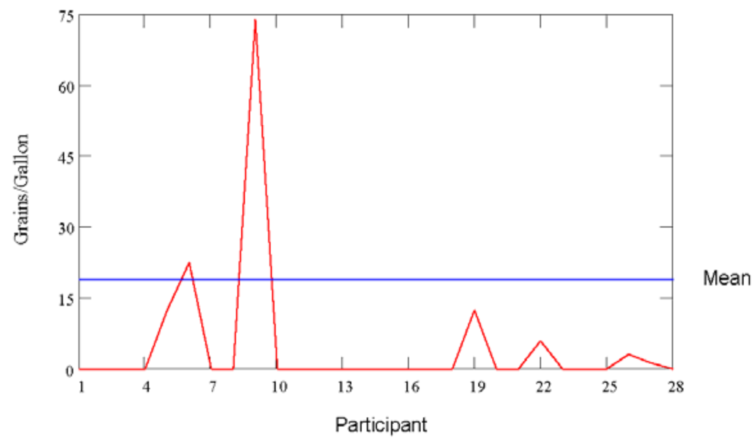
Number of participants = 8



21

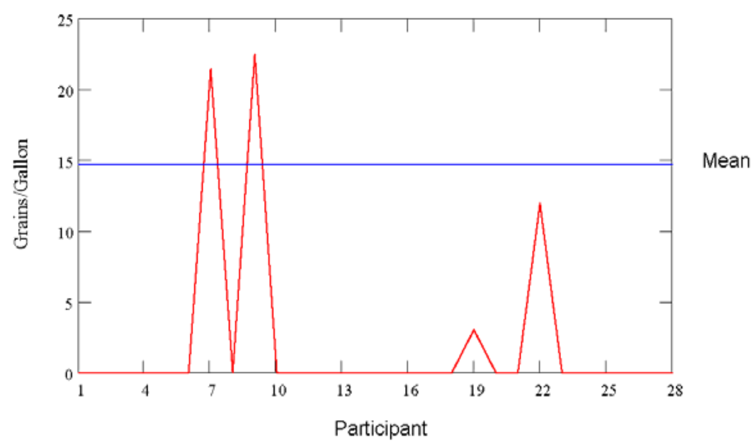
What is the Water total alkalinity in your service area?

Number of participants = 7



What is the Water Calcium content in your service area?

Number of participants = 4



22

4. CONCLUSIONS

- The survey results show that the mean lifetime for the first group of components (pumps, and plumbing fittings) was almost half of the that for the second group (Collectors, temperature sensors, tanks, pipe insulation and heat transfer fluid).
- The reliability indexes for the two groups were comparable at 6-8 out of a scale 10.
- The most reliable components in the first group were drain ball valve and horizontal shaft pump. For the second group, glass cover and collector enclosure were the most reliable.
- The least reliable components were mixing/tempering valve and untreated pipe insulation for the first and second group respectively.
- High system cost and bad experience with solar systems were identified as the most significant problems facing the SDWH industry.
- Improper installation was identified as the largest factor contributing to the relatively high maintenance cost of the SDWH systems.

APPENDIX A

List of Participants

Buckingham, D., Solar Services, Anaheim
Campbell, D., Solar Self-Help, Inc., Concord
Carrozza, A., Scholfield Solar Energy Company, Inc., Ventura
Combs, J., Conservative Energy Systems, Mesa
Ellis, B., Environmental Solar Design, Inc., North Hollywood
Emrich, M., Solarponics, Inc., San Luis Obispo
Gunderson, B., Sun, Wind, & Fire, Portland
Hamasaki, L., Sun Utility Network, Los Angeles
Hilchrist, J., North Canyon Construction, Phoenix
Howland, J., Solarhart USA, San Marcos
Hoyt, C., Gardner Heating & Plumbing, Reno
Jerry, D & D Plumbing, Reno
Kennedy, G., Occidental Power, San Francisco
Landry, M., Horizon Industries, Escondido
Loer, M., Sierra Pacific Power, Sacramento
Loken, N., Solar Assist, Eugene
Mancebo, S., Home Energy Solutions, Sacramento
McRae, M., Mac's Solar, Santa Barbara
Mizany, R., Solar Depot, Sacramento
Neary, M., Desert Sun Solar, Inc., Phoenix
Parker, D., The Energy Service Co., Eugene
Pelton, B., Morley Manufacturing, Cedar Ridge
Reed, P., Pacific West Solar, Phoenix
Soden, P., The Stanley Louis Co., Redondo Beach
Spiek, D., EWEB, Eugene
Straton, J., Stanford Energy, Mountain View
Summers, R., Summers Solar Systems, Eugene
Walters, A., Payson Solar Electric, Payson
Walters, M., Sun Systems, Scottsdale
White, R., California Solar, Thousand Oaks

APPENDIX B
SURVEY

Arizona State University

Durability and Reliability of Solar Domestic Hot Water Systems

SOLAR WATER HEATING SYSTEM COMPONENT LIFETIME SURVEY

Introduction

Thank you for your participation in a solar water heating system survey conducted by Arizona State University and the National Renewable Energy Laboratory (funded by the Department of Energy, DoE). The goal of this study is to gather information on product durability and reliability, based on field experience, which will be used to develop systems and components with longer lifetimes. Opinions from professionals, such as yourself, will be studied and summarized to provide a list of issues and their relative importance. This list will then be submitted to a DoE-sponsored technical board for preparation of technical briefs and for prioritizing recommendations for DoE research.

The responses to each question will be compared and summarized in a way which is informative and useful. All answers to the questions contained in this survey will remain strictly confidential and you should feel free to give your honest opinion.

After we receive your survey responses, we will schedule a brief personal interview with you at a place and time of your convenience. The purpose of this interview will be to quickly confirm your responses so that we do not make any mistakes in interpretation. This interview will also be an excellent opportunity for us to gain further insight from you on any responses which we do not fully understand. This interview will also give you the opportunity to suggest problems you have observed with solar water heating systems, solutions you have found to problems, or additions you think we should make to the survey.

Again, thank you for sharing your time and experience.

Byard Wood, PhD, P.E.
Professor of Mechanical Engineering

Kent Whitfield, Project Engineer

Betty Hicks, Research Specialist

SECTION I.

For questions A through I, please fill in your responses, in order of importance, on the lines provided. Place the most important (or most frequent) response on line 1 and the least important (least frequent) on line 5. Feel free to use the back of this survey if you have more than five responses to each question. If a response seems to fit equally well for two (or more) questions, feel free to write the question letter and number on the response line where you think it best belongs (such as "see A.2" to refer to your response on question A, number 2). If you have no opinion, or the question does not apply to you, please write "*NA*".

A. What types of solar water heating systems do you install (for example, open/closed loop, flat plate, thermosyphon, ICS etc.)?

1. ________________
2. ________________
3. ________________
4. ________________
5. ________________

B. What types of solar water heating systems do you regularly service?

1. ________________
2. ________________
3. ________________
4. ________________
5. ________________

C. Roughly, how many systems have you installed and/or regularly maintained in the local area?

circle one choice

1-25	**25-100**	**100-200**	**200-300**	**300-500**	**500 or more**

D. What do you perceive to be the biggest problem facing the solar water heating industry today?

1. ________________
2. ________________
3. ________________
4. ________________
5. ________________

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E. What factors (*in order of importance*) seem to cause the most maintenance problems with solar water heating systems in general?

1. ______
2. ______
3. ______
4. ______
5. ______

F. What general installation practice(s) (*in order of importance*) seem to cause most maintenance problems with solar water heating systems?

1. ______
2. ______
3. ______
4. ______
5. ______

For questions G through K. indicate maintenance problems with the specified systems if you install or maintain these systems.

G. What are the biggest maintenance problems you most often find with open loop (recirculation or draindown) systems?

1. ______
2. ______
3. ______
4. ______
5. ______

H. What are the biggest maintenance problems you most often find with ICS systems?

1. ______
2. ______
3. ______
4. ______
5. ______

I. What are the biggest maintenance problems you most often find with closed loop (glycol and/or drainback) systems?

1. ______
2. ______
3. ______
4. ______
5. ______

J. What are the biggest maintenance problems you most often find with thermosyphon systems?

1. ______
2. ______
3. ______

4. ____

5. ____

Question K applies if you install or service system types not specifically called-out in questions G through J.

System Type-_____________________________________.

K. What are the biggest maintenance problems you most often find with this system type?

1. ____
2. ____
3. ____
4. ____
5. ____

(please use the back of this sheet for more system types)

SECTION II.

In this next set of questions, please consider the average lifetimes of different solar water heating system components. The lifetime estimates should be indicative of solar water heating systems manufactured and installed within the last ten years. Feel free to estimate ranges or round numbers.

Example:

FIRST FAILURES OCCUR	*or*	FIRST FAILURES OCCUR
2-3		4

To indicate that first failures for this particular component occur from between two and three years, or for a different component, failures usually occur after about four years. If the amount of time to failure is less than one year, use a fraction (such as, 1/2 for six months) or use a whole number and the word "*mo.*" or "*months*". If you are not sure about an estimate, leave that line blank or write "*no opinion*".

The third column asks you, on a scale of **1** to **10**, to assign a reliability index to the part in question. A reliability of **10** should indicate that the part never fails in the field while a reliability of **1** should indicate that the part often fails after only a few months of service.

This information will be used to help determine the reliability and lifetime of different solar water heating components. This reliability can then be used to focus efforts of researchers and industry to develop solutions to premature component failures. Your input is crucial to this effort!

The lifetime estimates below should be for your service area or territory.

A. In general, how would you rate the water quality in your service area?___________________________

B. Have you measured or researched the total dissolved solids (ppm, µmho, etc.) for your area and if so could you share with us what it is?____

C. Do you know the total alkalinity (ppm or mg/L) or hardness (grains) area and if so could you share with us what it is?____

D. Do you know the calcium content (ppm or mg/L) area and if so could you share with us what it is?_____ ____

E. Does water quality affect the way in which you service a solar water heating system, and if so, how?

29

____

____

____

____

Please use the "ADDITIONAL PART" rows at the bottom of section F to: a) specify components that are not listed explicitly, or b) to point out a particular type/manufacturer of a general part that has, in your experience, a significantly different reliability than the average part. For example, if a component in general has a 20 year mean lifetime, but a particular manufacturer's same component fails after about two years, please list the manufacturer and/or specific component in the additional part box.

F.	FIRST FAILURES OCCUR	MEAN LIFETIME	RELIABILITY INDEX (1 - 10)	NO OPINION
AIR VENTS				
DRAINDOWN VALVE				
CHECK VALVES SPRING CHECKS				
CHECK VALVES FLAPPER CHECKS				
DRAIN BALL VALVES				
VENT VALVES				
MIXING (OR TEMPERING) VALVES				
PRESSURE AND TEMPERATURE (P-T) RELIEF VALVES				
PRESSURE (P) RELIEF VALVES				
PUMPS SHAFT HORIZONTAL				
PUMPS SHAFT VERTICAL				
COLLECTOR PASSAGE LEAKAGE				
F. cont.	FIRST FAILURES OCCUR	MEAN LIFETIME	RELIABILITY INDEX (1 - 10)	NO OPINION
COLLECTOR PASSAGE BLOCKAGE				
COLLECTOR COPPER ABSORBER PLATES, PAINTED SURFACE OUTGASSING OR GENERAL DETERIORATION				
COLLECTOR COPPER ABSORBER PLATES, SELECTIVE SURFACE OUTGASSING OR GENERAL DETERIORATION				
COLLECTOR ALUMINUM ABSORBER PLATES, PAINTED SURFACE OUTGASSING OR GENERAL DETERIORATION				
COLLECTOR ALUMINUM ABSORBER PLATES, SELECTIVE SURFACE OUTGASSING OR GENERAL DETERIORATION				
COLLECTOR FLUID PASSAGES ON ABSORBER BONDING OR CORROSION FAILURE				
COLLECTOR GLASS COVER				
COLLECTOR ENCLOSURE				

30

COLLECTOR GASKETS				
CONTROLLERS				
TEMPERATURE SENSORS				
STORAGE TANKS GLASS LINED				
STORAGE TANKS STEEL				
STORAGE TANKS THERMOSTAT FAILURES				
EXPANSION TANKS				
EXTERIOR PIPE INSULATION PAINTED COVERING				
EXTERIOR PIPE INSULATION ALUMINUM TAPE COVERING				
EXTERIOR PIPE INSULATION UNTREATED COVERING				
GLYCOL FLUID				
ADDITIONAL PART:				
ADDITIONAL PART:				
ADDITIONAL PART:				
ADDITIONAL PART:				
ADDITIONAL PART:				
ADDITIONAL PART:				
ADDITIONAL PART:				

G. Does your experience indicate that a shallow collector mounting angle (up to around 25°) influences the lifetime of solar water heating systems and components? Please circle one response.

strongly agree	agree	no opinion	disagree	strongly disagree

If you expressed an opinion in question G, do you believe that a shallow collector mounting angle *lengthens* or *shortens* the lifetimes of solar water heating systems and components? Please circle one response, or go on to the next question.

shortens	lengthens

H. Does your experience indicate that a latitude (or larger) collector mounting angle influences the lifetime of solar water heating systems and components? Please circle one response.

strongly agree	agree	no opinion	disagree	strongly disagree

If you expressed an opinion in question H, do you believe that a latitude (or larger) collector mounting angle *lengthens* or *shortens* the lifetimes of solar water heating systems and components? Please circle one response, or go on to the next question.

shortens	lengthens

I. Does your experience indicate that system oversizing (collector oversizing) influences the lifetime of solar water heating systems and components? Please circle one response.

strongly agree	agree	no opinion	disagree	strongly disagree

If you expressed an opinion in question I, do you believe that system oversizing (collector oversizing) *lengthens* or *shortens* the lifetimes of solar water heating systems and components? Please circle one response, or go on to the next question.

shortens	lengthens

J. In your experience, how often does vandalism of solar water heating collectors occur?
Please circle one response.

very often	often	sometimes	rarely	very rarely

K. In your experience, how often do you have to service, or find damage to collector racks?
Please circle one response.

very often	often	sometimes	rarely	very rarely

L. In your experience, how often does hail damage of solar water heating collectors occur?
Please circle one response.

very often	often	sometimes	rarely	very rarely

M. In your experience, how often do sensor lines require servicing?
Please circle one response.

very often	often	sometimes	rarely	very rarely

N. Are there any other factors which influence solar water heating system component lifetimes that we have not included but probably should? Please use the back of this sheet if you have more than three suggestions.

1. __________
2. __________
3. __________

SECTION III.

How would you most like to be kept informed of current improvements in the installation and maintenance of solar water heating systems? Please consider the different ways that this information could be provided to you and mark an "*x*" in the appropriate column. For example, if you find a particular method to be helpful or somewhat helpful, place an "*x*" in the "*helpful*" column. At the end of this section, please feel free to suggest other methods of obtaining reliability information to improve the installation, maintenance and service of solar water heating systems. (You can also use the comments section to suggest how to change the format of the survey questions.)

Please indicate your interest in the following ways of gaining information.

	VERY HELPFUL	HELPFUL	NO OPINION	NOT HELPFUL	COUNTER-PRODUCTIVE
guest speaker (SEIA)					
single sheet bulletins (mailed)					
single sheet bulletins (at chapter SEIA meetings)					
column in chapter newsletter					
multi-page technical briefs (requested by post card or by phone)					
Internet Web page					
computer bulletin board					
personnel training courses					
video taped training					

Comments:

Have you seen any recurring field problems not covered anywhere else in this document?

1

Thank you for your consideration and time.

An Analysis of Service and Repair Records from Two Sacramento Solar Companies

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1. INTRODCUTION

Of major interest in the solar community is the status of solar systems that have been in the field for a long period of time. In order to provide some insight into this issue, SRCC was funded to conduct a review of solar system service records. This report provides the results of an analysis of these records.

2. DATABASE DEVELOPMENT AND DATA ENTRY

An Internet based data entry form and accompanying database was developed to facilitate data entry recording and tabulation of a wide variety of solar repair and service records. The data entry form is provided in Appendix A. The data entry form was posted on the SRCC web site for data entry access. In turn, once records were entered into the form and submitted, the data was automatically routed to a computer database. Individuals entering data could access the data entry form on the web site, enter the data and submit each separate service record for database storage. Both the form and the database could, and were, constantly revised to accommodate new information gathered from the service records.

Once the data entry form and database were finalized, student assistants at the University of Nevada entered information into the database via the input form. After the data from the records had been entered, a validation review by a technical reviewer with solar thermal systems application experience was conducted for each database record. The purpose of this secondary review was to refine the entries and to identify system types, components, etc., that only those familiar with solar energy systems and the various system types, components and component manufacturers could identify. The reviewer in many cases had to use all available deductive skills to refine some of the entries. Therefore, the review of the entered data – prior to final analysis – was a very essential part of this project.

The service and repair records were obtained by National Renewable Energy Laboratory staff from two solar companies in Northern California and provided to SRCC for this project. The two companies were Bergquam Energy and William R. Murray & Sun, Inc., both based in Sacramento, CA.

All Bergquam service records were entered into the database and analyzed. The Bergquam service records were very detailed, as they had been submitted to Sacramento Municipal Utility District for invoicing purposes. The hard copies of the service records were also provided to the technical reviewer. Because of this, the confidence level of the information provided in these records is high. A total of 154 Bergquam service records were entered into the database. The Bergquam systems were serviced in 1999. The systems had been installed by various solar companies between 1989 and 1996. The majority of the installations occurred between 1992 and 1996, with one in 1989.

In contrast, the Murray & Sun service records provided were quite numerous but did not always provide detailed descriptions of the service calls, reasons for the calls, specifics of the problem, etc. Nevertheless, the reviewer, after initial data entry by the students, was able to deduce, often from rather cryptic descriptions, both the potential reasons for the service call, and more importantly, the cause of the perceived problem. The technical reviewer did not have access to the hard copies of the Murray service records. The end result is that there is a higher degree of confidence with the Bergquam information. A total of 976 Murray records were reviewed. Service dates were between 1982 and 1996. Installation dates were not provided.

3. SYSTEM TYPES

A variety of system types were identified. These included integral collector storage systems, active direct and indirect, thermosiphon, and for the Murray systems a number of pool, space heating and many unknown domestic hot water (DHW) as well as unknown systems. In many cases, the system type had to be deduced from the data base records by the technical reviewer. Neither the Bergquam or Murray records (and database entries) listed the specific type of system. Those that had enough information to determine that they were some type of solar water heating system were listed as "unknown DHW." The "unknown" category was provided to systems for which the reviewer did not have sufficient information or clues as to the type of solar system it was - DHW, pool, space heating, etc. Nevertheless, these were some type of solar water, pool or space heating systems.

Table 1 provides a listing of the type and number of systems included in this study.

Table 1 System types

System type	Bergquam	Murray
ICS	16	15
Direct forced circulation	0	87
Indirect forced circulation	129	52
Direct thermosiphon	1	26
Indirect thermosiphon	7	27
Phase change	0	1
Space heating	0	15
Space and DHW heating	0	11
Pool	0	242
Unknown DHW	1	428
Unknown type	0	66

The Bergquam information indicated that the primary type of system serviced was the indirect forced circulation, while pool heating and unknown DHW made up the majority of the Murray systems.

Appendix B provides detailed information on the types of systems as well as the corresponding system categories, symptoms, and problems for both the Bergquam and Murray data entry records that were technically reviewed.

4. SERVICE CALLS

Service call categories were listed on the database input form as component, installation, maintenance, or operation. In many cases data entry personnel and reviewer judgment was used to determine the possible cause of the service call since these categories were not directly identified on the service records. Also, in some cases, two types of service call categories were registered. In any event, the service call category provides a generalized overview of the possible reasons for the service call.

The primary reason for the Murray service calls, when identified, was related to component problems. This was also the case for the Bergquam systems, although operation is also revealed as a factor in the service call. Overall, it is difficult to truly determine the true cause of the service call problem since one category could easily reflect on another.

Table 2 Service call by category

Category	Bergquam	Murray	Total
Component	142	769	911
Installation	16	37	53
Maintenance	2	64	66
Operation	4	103	107

5. SYMPTOMS

A wide variety of symptoms were identified. In order to properly evaluate the symptoms, they were listed by various categories such as water related symptoms, leak related symptoms, and so forth. The Bergquam records provided more reliable information regarding the reason for the service call. The Murray records do not appear to have been as specific. It appears that they primarily chronicled the problem the service personnel identified once at the site.

This symptoms breakdown is provided with caution since many of the symptoms may not have been clearly listed on many of the service records. That is, the service record may have indicated that there was a collector leak, and therefore it is assumed that the owner would have called the service company with this symptom in mind (collector leak). Or, it could be that the owner called in a symptom related to "water coming off the roof." On the other hand, symptoms related to the temperature of the household water would no doubt have been the cause of the service call on the part of the owner. Other listed symptoms such as "pump cycles after dark" could well have been reported by the owner as "no hot water in the morning" and identified as the former by service personnel. In any event, the listed symptoms do reflect some of the problems that either owners or service personnel have identified.

Table 3 provides an overview by specific category of the number of symptoms identified. A detailed listing and identification of the symptoms within each category is provided in the individual symptom identification tables later in this report.

The two major symptoms identified were leak and water usage related, both symptoms that are obviously easily identifiable on the part of system owners.

Although the listing of valve symptoms is minimal, valves nevertheless are shown in the ensuing problem section as being some of the most problematic components of these solar systems. Unless it is a valve showing observable failure, such as a spewing freeze valve in the middle of summer, system owners would not be aware of many valve problems, which nevertheless affect overall system operation – and malfunction. An air vent not functioning would be an example of this unless the valve is visually observed to be leaking from its port.

Table 3 Symptoms by general category

Symptom category	Bergquam	Murray	Total
Leak related	40	383	422
Usage water related	44	98	142
Pump related	16	57	73
Service related	3	43	46
Noise related	0	24	24
Collector related	3	11	14
Water heater related	0	7	7
Draining related	0	5	5
Air related	0	5	5
Freeze related	0	4	4
Valve related	0	3	3
General related	41	319	360

It is questionable whether the owner versus service personnel identified some of these symptoms, air related symptoms being a case in point.

The General Symptoms listings were more for data entry and project reviewer – a generic category as evidenced by the specific general symptoms table below – especially those that could not be determined from the service records. The vast majority of these general symptoms are for "no symptoms listed in the repair order" and have been delineated as such by data entry personnel. In many cases, this section of the data entry form was left blank. Undoubtedly, this could indicate that service personnel did not have the symptoms listed on a service order, but instead were given an address and were notified of the symptom once at the site. In the end, it appears that not all symptoms were reported, but there is still sufficient data to provide a general overview of the most prominent symptoms.

a. Leak related symptoms

A large number of leak related symptoms were identified. The Bergquam records indicated that 40 systems had leak problems while the Murray systems had 382. The majority of these were related to water coming off the roof and general system leaks. System owners could very well have reported these since the symptoms are obvious and easily identifiable on the part of the layman.

Table 4 Leak related symptoms

Symptom	Bergquam	Murray	Total
System leaks	35	353	388
Water comes off roof	4	29	33
System leaks. Not solar related.	1	0	1

b. Water related symptoms

The primary symptom that led to the service call in this category was “no hot water.” This was closely followed by “not enough hot water.” Very few instances revealed that “no hot water” was the symptom while “water not hot enough” and “water too hot” were very infrequently listed as symptoms. All of these symptoms would be quite obvious to the system owner.

Table 5 Water related symptoms

Symptom	Bergquam	Murray	Total
No hot water	29	67	96
Not enough hot water	12	17	29
No water	0	2	2
Water not hot enough	2	4	6
Water too hot	1	5	6
No hot water in morning	0	2	2
Toxic smell to water	0	1	1

c. Service related symptoms

Listed below are the various reasons provided for service related symptoms as identified in the service records.

Table 6 Service related symptoms

Symptom	Bergquam	Murray	Total
Scheduled checkup	0	20	20
Winterized system	0	9	9
System check	0	3	3
Spring tune up	0	1	1
Bid for repair	0	1	1
Solar needs to be connected to new water heater	1	0	1
System is operating and needs to be remounted	1	0	1
System needs to be reinstalled	1	0	1
System removal requested	0	1	1
System needs parts	0	1	1
System not connected	0	1	1
Check work of roofers	0	1	1

Owner shut down system	0	1	1
Owner wants explanation of how system works	0	1	1
Complete installation	0	1	1
Install pool heater	0	1	1

d. Pump related symptoms

The majority of pump related symptoms were caused by the pump not starting, followed by noisy pumps and pump running continuously. Although the pump not starting symptom is listed in the pump category, it is conceivable that the problem itself is caused by some other system component, such as a controller, sensor, etc. A total of 73 pump related symptoms were identified. Note that this includes DHW as well as pool system pumps.

Table 7 Pump related symptoms

Symptom	Bergquam	Murray	Total
Pump dos not start	10	17	27
Pump runs continuously	2	22	24
Noisy pump	3	7	10
Pump cycles continuously	0	5	5
Pump cycles after dark	0	3	3
Pump has burn marks	1	0	1
Pump needs cleaning	0	1	1
No power to pump switch	0	1	1
Pool pump not priming	0	1	1

e. Noise related symptoms

There were no noise related symptoms with the Bergquam systems while the Murray records identified 24 noisy systems and one interesting "whistling when hot" symptom.

Table 8 Noise related symptoms

Symptom	Bergquam	Murray	Total
Noisy system	0	23	23
Whistling when hot	0	1	1

f. Collector related symptoms

There were few collector related symptoms reported. It is conceivable that the leak related symptoms were in many instances caused by leaking collectors, but could have been reported by the system owner as "leak" related symptoms and are thus included in the leak related symptoms section above. The majority of the symptoms listed in Table 9 are related to collector enclosure problems.

Table 9 Collector related symptoms

Symptom	Bergquam	Murray	Total

Panels and rack need repair	0	1	1
Sagging glass in collector	2	0	2
Pool collectors do not drain	0	2	2
Broken panel	1	0	1
Broken glazing	0	1	1
Cover blew of collector	0	1	1
Wind damage to collector	0	1	1
Brackets down	0	1	1
Metal is hanging down and coming off	0	1	1
Bad plate	0	1	1
Panels slipping due to brittle plastic brackets	0	1	1
Put covers on solar panels	0	1	1

g. Water heater related symptoms

There were no water heater related symptoms identified in the Bergquam records, while 7 systems with these symptoms were recorded with the Murray systems. Although included in this solar analysis, it could be claimed that certain symptoms could occur regardless of whether the heater was integrated into the solar system - heater pilot light and gas burner problems being a case in point.

Table 10 Water heater related symptoms

Symptom	Bergquam	Murray	Total
Heater pilot light will not stay on	0	2	2
Problems with water heater	0	1	1
Correct plumbing to water heater	0	1	1
Gas burner will not light	0	1	1
Ringing from storage tank	0	1	1
Burning smell	0	1	1

h. Draining related problems

There were no draining related symptoms identified in the Bergquam records, while 5 systems were recorded with the Murray systems. Draining symptoms do not appear to be a major problem and were more than likely associated with failure of the automatic draindown valve. See automatic draindown valve problems below.

Table 11 Draining related symptoms

Symptom	Bergquam	Murray	Total
Continuous draining	0	3	3
Draindown problem	0	1	1
System does not drain	0	1	1

i. Air related symptoms (Space heating system)

This is a symptom that would be quite easily identifiable by a homeowner.

Table 12 Air related symptoms (space heating)

Symptom	Bergquam	Murray	Total
No heat	0	1	1
Space heating not working after freeze	0	1	1
Air coming through very cool	0	1	1
Blowing cold air	0	1	1
Air in pool	0	1	1

j. Freeze related symptoms

Only 4 freeze related symptoms were identified in the Murray systems. This type of symptom could easily be included in leak related symptoms. Many homeowners are often not aware of the cause of water coming off the roof.

Table 13 Freeze related symptoms

Symptom	Bergquam	Murray	Total
Freeze damage	0	4	4

k. Valve related symptoms

No valve related symptoms were reported in the Bergquam records while the Murray records indicated 3 valve related symptoms. It is unclear as to the type of valve causing the symptom.

Table 14 Valve related symptoms

Symptom	Bergquam	Murray	Total
Valve makes noise and releases water at 52 F	0	1	1
Broken automatic valve stem	0	1	1
Automatic valve not shutting off	0	1	1

l. General symptoms

The general symptom category encompasses symptoms that were not identified or were assumed by the reviewer. It is provided here only for general information.

Table 15 General symptoms

Symptom	Bergquam	Murray	Total
No symptoms listed in repair order	22	240	262
System working – unspecified symptom	1	22	23
System not working – unspecified symptoms	4	18	22
Unknown symptoms	0	19	19
No symptoms	13	6	18
Not solar related	0	12	12
Unknown problem	0	2	2

System has multiple problems	1	0	1

6. PROBLEMS

Identifying system problems and the related components is at the heart of this study. What problems were encountered, and specifically, which components are the most problematic in system design, installation and long-term performance? This information can provide basic information and can also be used in assisting system designers, installers and developers of solar thermal system instruction curriculum.

Caution must be taken in reviewing the overall numbers and how this affects the perception of solar systems, since a weak link of this analysis is that it is not know what percentage of total installations existing in that specific Sacramento area are represented by the service records. Interested parties reviewing the information in this report would be better served in concentrating on the specific findings – that is, the types of problems that can occur and those components that have a higher incidence of problems – and what implications these have on future system installations.

Several key questions cannot be answered. This is the limitation of obtaining information from past written notes made by service personnel which were in many instances less than specific. Clarification cannot be obtained. In other words, did the failure of a certain component result from poor installation practices? For example, being in contact with sharp objects could cause a failed sensor wire. This would not be clearly spelled out in the service record, but instead would be listed as a defective sensor wire. What was the cause of defective pumps? Was the defect based on a manufacturing problem or was it caused by some abnormality in the overall solar system? Or was it cause by agrresive water? What caused the controller to become defective? Was it a manufacturing defect, a lightning strike, insects in the controller, etc.? Unfortunately, many of these questions cannot be answered.

In addition, what exactly should be considered a "problem" and what should be considered the result of normal wear and tear and the anticipated end of a component's operational lifetime? Numerous water heater failures were reported, but could that be a normal occurrence and not a problem in the sense of problems being caused by defective parts or poor installation? Could the heaters have reached their expected lifespan? The repair records do not clarify the age of a water heater; thus it is impossible to determine whether the tank failed due to a manufacturing defect, water conditions, improper plumbing, or a host of other possibilities.

If, on the other hand, a sensor is not properly attached thereby affecting the performance of a solar system, this then becomes a definite problem caused by poor installation and has nothing to do with the sensor itself. Therefore, common sense and a degree of technical judgment have to be used when reviewing the numbers provided in this report.

Table 16 lists the problems by general component and/or category. A detailed breakdown by subcategory of each problem is provided in specific component tables listed below.

Table 16 Problems by category

Problem category	Bergquam	Murray	Total
Collector	24	141	165
Collector mounting	12	38	50
Differential control	14	63	77
Photovoltaic control	0	2	2
Sensor	52	86	138
Sensor wiring	23	36	59
Timer control	7	2	9
Solar storage tank	22	67	89
Electric auxiliary tank	26	9	35
Gas auxiliary tank	0	12	12
Instantaneous gas heater	0	4	4
AC pump	49	96	145
DC pump	0	0	0
Drainback tank	5	11	16
Expansion tank	2	1	3
Heat exchanger	4	8	12
Heat transfer fluid	28	34	62
Piping	1	2	3
Piping roof penetration	0	2	2
Exterior insulation	29	25	54
Pressure	1	4	5
Temperature gauge	1	2	3
Transformer	15	1	16
Air vent	0	58	58
Automatic draindown valve	0	81	81
Anti-scald valve	1	2	3
Cold supply isolation valve	1	0	1
Check valve	1	22	23
Fill/drain valve	3	12	15
Freeze valve	0	29	29
Isolation valve (includes dhw and pool)	3	54	57
Tempering valve	46	29	75
Pressure relief valve	0	1	1
Temperature pressure relief valve – water heater	4	8	12
Temperature pressure relief valve – collector	2	14	16
Vacuum breaker	5	19	24

Valves appear to be the most problematic component of solar systems. This could be due to the fact that valves are the most numerous components of most individual solar systems. In other words, there are more valves incorporated in an individual solar system than pumps, controllers, collectors, etc. The variety of valves that perform a number of functions is also widespread in systems. Some are static, in the sense that they rely on manual operation, such as isolation and drain valves, while others depend on automatic mechanical action to function properly. These include automatic draindown, freeze, pressure relief, etc. It appears that because of this, valve problems are quite frequent and numerous.

Control and control wiring were reported as the second most problematic part of solar systems. The "brains" of any solar water heating system, that is, those systems that rely on active pump circulation for heat transfer, is the control strategy that incorporates a controller, be it differential, photovoltaic, or timer, as well as sensors, wiring, wiring connections, etc.

Differential controllers and sensors make up the vast majority of problems in this category. Unfortunately, the largest description provided for problem controllers was "defective controller." Of particular interest would be determining why the controller was defective – was it due to electronic malfunction, lightning strike, etc. Detailed information as to why the component failed was not provided. Sensors not properly attached/secured is also indicated quite frequently, which reflects on installation practices.

The majority of collector problems are leak related while mounting problems represent a smaller segment of the overall problems. Collector leaks were not specifically identified as far as the exact cause and location, but it appears that a large number were caused by freeze damage.

Table 17 Ranking of problems by category

Problem category	Total number
Valves	413
Control and control wiring	285
Collector and collector mounting	215
Pumps	145
Solar and auxiliary tanks	140
Heat transfer fluid	62
Exterior insulation	54
Drainback, expansion tank	19
Heat exchanger	12
Piping and piping roof penetration	5
Pressure	5

a. Collector problems

Leaks appear to be the most common problem with solar collectors. How the leak was caused, whether from manufacturing defects, corrosion or through freeze conditions, was not clearly specified. Of particular concern was the "leaking - source unknown" category since this does not shed light on the cause of the leak. The large number of "leaking due to freeze damage" is interesting since the majority of the systems were of the indirect type. There nevertheless were a large number of direct forced circulation systems which would indicate that in areas such as Northern California perhaps these are not the ideal systems to use due to freezing conditions.

Table 18 Collector problems

Problem	Bergquam	Murray	Total
Leaking (source unknown)	6	42	48
Leaking due to freeze damage	2	29	31
Defective collector	2	10	12
Glazing is broken	2	10	12
Unknown problem	0	11	11
O-rings defective	0	10	10
Riser to header connection leaking	8	0	8
Header tubes leaking	0	7	7
Collector removed for re roofing	0	6	6
Riser tubes leaking	0	5	5
Enclosure structural problem	2	2	4
No fluid flow in collector	2	0	2
Glazing extremely dirty	0	2	2
Plug on pool panel defective	0	2	2
Collector removed permanently	0	2	2
Panels blew off roof	0	1	1
Structural damage to roof from collector leak	0	1	1
Collector bypassed	0	1	1

b. Collector mounting problems

The collector mounting problems reveal an installation problem that in many cases should have been avoided with proper installation methods and care.

Table 19 Collector mounting problems

Problem	Bergquam	Murray	Total
Defective	3	16	18
Collector not firmly attached to roof	1	5	6
Improper structural mounting method	2	2	4
Flashing not sealed	1	3	4
Roof penetration not sealed	0	4	4
Leak at mounting points	1	3	4
Unknown problem	0	3	3
Mounting bolts not secured	2	0	2
Improper roof flashing used	1	1	2
Collector not tilted for drainage	0	1	1
Improper orientation (azimuth)	1	0	1

c. Differential controller problems

As stated previously, it is unclear as to why the controller was defective. Was it due to electronic malfunction, lightning strike, corrosion of electronic components, etc.? Detailed information as to why the component failed was not provided. Several of the categories such as "switch on On position" and "loose connections at sensor terminal" are installation issues.

Table 20 Differential control problems

Problem	Bergquam	Murray	Total
Defective controller	10	43	53
Unknown problem	0	7	7
Controller operates only in manual mode	1	2	3
Improperly programmed	0	2	2
System shuts off at wrong high limit or runs continuously	0	2	2
No power to the controller	2		2
Switch on "On" position	1	0	1
On/Off points set too high	0	1	1
High temperature limit setting inaccurate	0	1	1
Loose connections at sensor terminal	0	1	1
Controller stays on all the time	0	1	1
Controller turns on and off rapidly	1	0	1
Control calling for heat when thermostat is turned down	0	1	1

d. Photovoltaic control problems

Records indicate that very few photovoltaic controlled systems were installed and thus very few problems were encountered with the modules themselves. The listed problems are due to poor system design and installation.

Table 21 Photovoltaic control problems

Problem	Bergquam	Murray	Total
PV module shaded	0	1	1
PV module too small for head	0	1	1

e. Sensor problems

A large number of defective sensors were identified. These include both collector and water heater sensors. The cause of the defect was not indicated. Once again, the findings indicate that in many cases, the improper installation of the sensors is the primary cause of the problem.

Table 22 Sensor problems

Problem	Bergquam	Murray	Total
Defective sensor	5	45	50
Defective collector sensor	28	11	39
Defective tank sensor	11	2	13
Improper mounting location (collector)	0	8	8

Improper connection method	0	7	7
Sensor not protected from environment	1	5	6
Collector sensor not properly attached/secured	5	1	6
Unknown problem	0	3	3
Tank sensor not properly attached/secured	2	0	2
Sensor not installed (required)	0	2	2
Sensor and controller not compatible	0	1	1
Defective snap switch	0	1	1

f. Sensor wiring problems

The cause of the "defective sensor wiring" was not indicated. It is thus unclear whether the defect is the result of poor ultraviolet ray protection and ensuing degradation of the external wiring or whether the wiring was somehow damaged during post installation activities. The findings reveal that poor installation practices are very often the cause of sensor wiring problems.

Table 23 Sensor wiring problems

Problem	Bergquam	Murray	Total
Defective sensor wiring	5	13	18
Defective wire connections	7	2	9
Unknown problem	0	9	9
Shorted collector sensor wiring	4	1	5
Sensor wires reversed	2	2	4
Open collector sensor wiring	2	0	2
Shorted water heater sensor wiring	1	1	2
Sensor wire run not secured	0	2	2
Sensor wires not connected	0	2	2
Sensor wires crimped	0	1	1
Sensor wires chaffed from obstructions	0	1	1
Wiring insulation chewed by rodents	1	0	1
Line cord problem	0	1	1
Roof wiring penetrations not sealed properly	0	1	1
Open water heater sensor wiring	1	0	1

g. Timer controller problems

Table 24 Timer control problems

Problem	Bergquam	Murray	Total
Current time incorrect	4	0	4
Defective timer	2	1	3
Wrong on/off time	0	1	1
Unplugged from power source	1	0	1

h. Solar storage water heater problems

Leaks are the primary source of solar storage tank problems. Thermostat problems appear to be quite numerous, whether it be that the thermostats were defective, were set too low, or tripped due to overheating. Water conditions do not appear to have been a problem.

Table 25 Solar storage water heater problems

Problem	Bergquam	Murray	Total
Tank fitting leak	10	9	19
Defective element	5	11	16
Internal tank leak	1	10	11
Unknown problem	0	11	11
Defective water heater	1	7	8
Defective thermostat	2	6	8
Thermostat tripped (overheating)	0	6	6
Thermostat set too low	2	0	2
Thermosiphon tank leak	0	1	1
Defective thermostat wiring	0	1	1
Voltage to water heater inadequate	0	1	1
Defective circuit breaker	0	1	1
Thermosiphon tank shell coming apart	0	1	1
Tank outer shell cracked	0	1	1
White deposits in storage tank	1	0	1
Solar flow blocked due to tank bottom calcification	0	1	1

i. Electric auxiliary water heater problems

Element and thermostat problems dominate the electric water heater category.

Table 26 Electric auxiliary water heater problems

Problem	Bergquam	Murray	Total
Defective element	8	1	9
Defective tank	4	3	7
Defective thermostat	4	1	5
Upper thermostat set too low	4	0	4
Thermostat tripped	2	0	2
Unknown problem	0	2	2
Internal tank leak	1	0	1
Leak at element bolt	0	1	1
Lower thermostat set too low	1	0	1
No electric power to tank	1	0	1
Old heater inefficient without solar	1	0	1
Not properly insulated	0	1	1

j. **Gas auxiliary water heater problems**

Table 27Gas auxiliary water heater problems

Problem	Bergquam	Murray	Total
Pilot light off	0	3	3
Failure to ignite	0	2	2
Pilot valve defective	0	2	2
Defective tank	0	1	1
Internal tank leak	0	1	1
Defective thermocouple	0	1	1
Loose thermocouple connection	0	1	1
Unknown problem	0	1	1

k. **Instantaneous gas water heater problems**

Table 28 Instantaneous gas water heater problems

Problem	Bergquam	Murray	Total
Unknown problem	0	4	4

l. **AC pump problems**

The majority of pump problems are related to leakage at both the pump and pump fittings. The cause of the pump leakage was not identified in the service records. Leakage at pump connections could be seen as an installation issue.

Table 29 AC pump problems

Problem	Bergquam	Murray	Total
Defective pump	19	57	76
Defective rotor	21	0	21
Unknown problem	0	13	13
Leak at pump connections	3	5	8
Pump failure	3	3	6
Air trapped in pump	0	6	6
Replaced cartridge	0	3	3
Leak in pump	0	3	3
Motor failure	0	2	2
Defective capacitor	0	2	2
Defective gasket	0	1	1
Bearing dry (need lubrication)	1	0	1
Loose pump mounting flanges	0	1	1
Improperly installed	0	1	1
Stuck shaft, impeller, or coupling	1	0	1
Required pump not installed	1	0	0

m. Drainback tank problems

Drainback tank problems are minimal. The primary problem appears to be that the tank water level was found to be too low. This, in turn, is related to the other listed drainback tank problems.

Table 30 Drainback tank problems

Problem	Bergquam	Murray	Total
Tank water level too low	3	3	6
Tank leaks	0	2	2
Improper fluid level	0	2	2
Unknown problem	0	2	2
Defective tank	0	1	1
Level indicator leaks	1	0	1
Tank is empty of fluid	1	0	1
Tank overfilled	0	1	1

n. Expansion tank problems

The large majority of systems records were for indirect systems. In light of this, the small number of expansion tank and heat exchanger problems appears to indicate that these two system components are reasonably reliable.

Table 31 Expansion tank problems

Problem	Bergquam	Murray	Total
Tank required but not installed	1	1	2
Defective expansion tank	1	0	1

o. Heat exchanger problems

Table 32 Heat exchanger problems

Problem	Bergquam	Murray	Total
Heat exchanger leak	2	3	5
Defective heat exchanger	0	3	3
Inefficient due to clogging	1	0	1
Isolated from system	1	0	1
Air in heat exchanger	0	1	1
Unknown problem	0	1	1

p. Heat transfer fluid problems

This category reveals that heat transfer fluid charging and mixture combinations are of concern for those systems using pressurized heat transfer loops. The specific cause for recharging was not provided, while mixture problems are assumed to be installation concerns.

Table 33 Heat transfer fluid problems

Problem	Bergquam	Murray	Total
Recharge of fluid required	0	19	19
Insufficient glycol mixture	18	0	18
Loss of fluid due to a leak	2	6	8
Fluid level low	0	7	7
No fluid in system	1	1	2
Low pressure in loop	3	0	3
No pressure in heat transfer loop	2	1	3
Loss of chemical stability	1	0	1
Wrong type of glycol used	1	0	1

q. Piping problems

Very few problems related to overall system piping were encountered. Where the fluid leaks were located was not specified, but presumably they were at plumbing fittings.

Table 34 Piping problems

Problem	Bergquam	Murray	Total
Fluid leak in piping	0	2	2
Entrapped air	1	0	1

r. Piping roof penetration problems

There were very few leaks at the roof piping penetrations. This is a marked improvement over the findings revealed in the collector mounting section, which indicated numerous problems with collector mounting penetration sealing.

Table 35 Piping roof penetration problems

Problem	Bergquam	Murray	Total
Leak at roof piping penetration	0	2	2

s. Exterior insulation problems

It is interesting to note that the largest exterior insulation problem had to do with the use of foil tape. In many cases, the use of air conditioning industry aluminum tape is an ideal choice for the protection of exterior pipe insulation. Unfortunately, the cause or specifics of how the tape deteriorated is not provided. On a positive note, it appears that exterior pipe insulation protective coating was not a widespread problem.

Table 36 Exterior insulation problems

Problem	Bergquam	Murray	Total
UV protective foil tape deteriorating	17	3	20
Not used (required)	2	8	10
Defective insulation	6	3	9
New insulation needed	0	7	7
Insulation deteriorating (non uv protective)	2	4	6

Animals destroying insulation	1	0	1
Wrong type (foam/plastic) used	1	0	1

t. Pressure related problems

Table 37 Pressure related problems

Problem	Bergquam	Murray	Total
No pressure	0	2	2
Pressure problem	0	1	1
No collector loop pressure	1	0	1
Pressure too high, pool sweep runs with solar on	0	1	1

u. Temperature gauge problems

Table 38 Temperature gauge problems

Problem	Bergquam	Murray	Total
Defective gauge	1	1	2
Leaking at body of gauge	0	1	1

v. Transformer problem

Undoubtedly, this problem was isolated to one specific system manufacturer's installation since transformers are not usually components that are included in the design of conventional solar thermal systems.

Table 39 Transformer problem

Problem	Bergquam	Murray	Total
Defective transformer	15	1	16

w. Air vent problems

The leading cause of the defective air vent was not provided. Neither was the result of freeze damage to these components. Nevertheless, air vents appear to be problematic and require periodic inspection and service.

Table 40 Air vent problems

Problem	Bergquam	Murray	Total
Defective air vent	0	39	39
Inoperative due to freeze	0	9	9
Internal leak	0	3	3
Not installed (required)	0	2	2
Air in hot water line	0	1	1
Needs an air vent	0	1	1
Leak at plumbing fitting	0	1	1
Not operating (air in system)	0	1	1
Unknown problem	0	1	1

x. Automatic draindown valve problems

Quite a large number of problems were encountered with the automatic draindown valves, the majority being a specific automatic draindown valve used in residential solar water heating systems in the 1980s and 1990s.

Table 41 Automatic draindown valve problems

Problem	Bergquam	Murray	Total
Valve defective	0	65	65
Valve stuck in drain position	0	5	5
Valve stuck in fill position	0	4	4
Unknown problem	0	4	4
Does not open or close fully	0	1	1
O-ring defective	0	1	1
Noisy operation	0	1	1

y. Anti-scald valve problems

Anti-scald valve problems appear to be quite small. It is unclear in many instances whether service personnel may have interchanged the name "anti-scald" and "tempering" valve. Data entry personnel used the identification provided by the service records. The technical reviewer was at times able to further define the specific type of valve (anti-scald versus tempering) whenever the manufacturer or model number of the valve was provided. The listing of the manufacturer or model versus generic name was very infrequent. Therefore, review of anti-scald valve and tempering/mixing valves may have to be lumped together. (See Tempering Valve Problems below.)

Table 42 Anti-scald valve problems

Problem	Bergquam	Murray	Total
Valve defective	1	0	1
Needs internal rebuilding	0	1	1
Unknown problem	0	1	1

z. Cold supply valve problem

Table 43 Cold supply valve problem

Problem	Bergquam	Murray	Total
Internal leak at seals	1	0	1

aa. Check valve problems

Details concerning the specific cause for the defective check valves were not provided. Once again, the findings reveal that the installation – actually no installation – of the valve was a problem.

Table 44 Check valve problems

Problem	Bergquam	Murray	Total
Defective valve	0	11	11

Valve stuck open – internal leak	1	5	6
Not installed (required)	0	5	5
Unknown problem	0	5	5
Leaking	0	1	1

bb. Fill/Drain valve problems

The nature and specific cause of the defective valve was not provided. It is assume that this type of valve would have leak problems at the seals. Failure to install fill/drain valves was noted in several instances. This is an installation issue.

Table 45 Fill/Drain valve problems

Problem	Bergquam	Murray	Total
Valve defective	0	5	5
Not installed (required)	0	5	5
Packing nuts loose	2	0	2
Unknown problem	0	2	2
Internal leak at seals	1	0	1

cc. Freeze valve problems

It is quite interesting to see that freeze valves are used in the Sacramento area. It had always been assumed that these valves were used primarily in warmer climates that encountered mild and short-lived freezing conditions in the winter – such as Florida. Nevertheless, review of the records indicates that numerous direct systems were indeed installed in the Sacramento area. The freeze valves undoubtedly were used on these systems. The service records did not indicate the age of these valves or what the specific defect was. It could be that the category “valve defective” could also have been noted by service personnel as “valve leaking” since the two critical problems that could be encountered are that the valve leaks or it does not operate as designed, resulting in failure of other system materials and components – piping and collectors.

Table 46 Freeze valve problems

Problem	Bergquam	Murray	Total
Valve defective	0	17	17
Valve leaking	0	9	9
Unknown problem	0	2	2
Freeze plug problem	0	1	1

dd. Isolation valve problems

Isolation valves represent both those used in solar DHW as well as in solar pool heating systems. In large part, the service records did not indicate whether the valves were automatic or manual.

Table 47 Isolation valve problems

Problem	Bergquam	Murray	Total
Valve defective	2	18	20

Defective motorized pool valve	0	16	16
Not installed (required)	0	8	8
Unknown problem	0	7	7
Improper setting (position)	1	3	4
Leak at seats	0	1	1
Isolation valve not seating completely	0	1	1

ee. Tempering valve problems

Service records indicate that a large number of tempering valves encountered problems. As stated in the above anti-scald valve problems section, it questionable whether the service personnel differentiated precisely between a true "safety" (in the legal sense) anti-scald valve and a "Btu conserving" tempering valve. Nevertheless, results do indicate that tempering valves are a problem concern.

Table 48 Tempering valve problems

Problem	Bergquam	Murray	Total
Valve defective	19	10	29
Needs internal rebuilding	15	12	27
Improper temperature setting	6	2	8
Stuck due to deposits	4	0	4
Leaking	1	2	3
Unknown problem	0	2	2
Loose packing nut	1	0	1
Required – due to water being too hot	0	1	1

ff. Pressure relief valve problem

Table 49 Pressure relief valve problem

Problem	Bergquam	Murray	Total
Needs internal rebuilding	0	1	1

gg. Water heater temperature-pressure relief valve problems

Table 50 Water heater temperature-pressure relief valve problems

Problem	Bergquam	Murray	Total
Valve defective	3	5	8
Internal leak	1	3	4

hh. Collector loop temperature-pressure relief valve problems

Table 51 Collector loop temperature-pressure relief valve problems

Problem	Bergquam	Murray	Total
Valve defective	1	9	10
Discharge not routed to proper location	0	2	2
Leaking	1	0	1
Leaking at port – did not reseat after opening	0	1	1
Relief valve discharge is killing lawn	0	1	1

Unknown problem	0	1	1

ii. Vacuum breaker valve problems

Table 52 Vacuum breaker valve problems

Problem	Bergquam	Murray	Total
Valve defective	4	10	14
Leaking	1	5	6
Unknown problem	0	3	3
Valve has been plugged	0	1	1

7. SERVICE FEES – BERGQUAM

The following provides an overview of the labor and material charges presented for the various services listed on the service records. The Bergquam records were reviewed since complete hard copy service cost invoices were provided to the technical reviewer. Since these detailed invoices had to be provided to SMUD for billing purposes they contained very valid service cost information.

Average labor charges: $199.17
Average parts charges: $ 95.93
Average total charges: $295.11

Labor costs ranged from $50 to $700 while the range for parts was from $0 to $625. Totals ranged from $80 to $1200. See Appendix C for a detailed listing of the service fees.

Solar Hot Water System (SHWS) Reliability:
Feedback from Sacramento Area SHWS Contractors

Jay Burch
National Renewable Energy Laboratory
1st Draft 2/16/94; 1st Revision 6/30/94; 2nd Revision 9/23/94

DRAFT REPORT: DO NOT QUOTE

Summary

As part of the 1994 DOE reliability task, NREL staff visited with SHWS contractors and manufacturers in the Sacramento area, to solicit their experiences and opinions on reliability issues. Results include:

X. Detailed insights on design and installation issues were given (see Section IV). The most troublesome component identified was the mixing valve. The probable cause of reported high failure is installation without a thermal trap, in violation of OEM guidelines. Such information, when substantiated by consensus or research, should feed into projected SEIA Ainstallation training manuals≅ and SRCC=s AManual of Practices≅ for design review and transfer to manufacturer=s for inclusion in their manuals.

X. Improvements in the programmatic structure of SRCC were proposed to better communicate field experience to the SRCC board, to the design review team, and amongst SEIA members (See Section II).

X. Qualitative estimates for mean lifetime of some components were obtained (see Section III, and Appendix 3), but the problem is compounded by the fact that the failure rates depend heavily upon system temperatures (which depend on local climate and site load) and water quality. Documented, hard repair **rate** data will be difficult to obtain.

I. Sacramento data

Initial contacts were obtained from the 11/93 SRCC/SMUD Sacramento meeting attendance record and directly from Cliff Murley of SMUD's solar program. From 1/17/94 to 1/19/94, staff visited with 10 individuals representing 8 firms in the Sacramento, California area. Based upon internal and SMUD feedback, the 1st draft was revised in July 1994, and sent to contributors for comment. The same individuals were visited again from 9/15/94 to 9/20/94, to get further information and obtain feedback on the draft report circulated to participants. Without exception, the discussion was earnest and productive. The individuals and their firms that were visited are:

1) Jim Bergquam, Bergquam Energy
2) Michael Proulx and Phil Lean, Solar Depot/Sacramento

3) Mike Lohr, Sierra Pacific
4) Bob Pelton, Morley Manufacturing
5) Dennis Aufdenkamp, Frontier Energy Systems
6) Scott Williamson and Ed Murray, William Murray and Sun
7) Al Rich, A. C. Rich and Sun
8) Skip Mancebo, Solmax/Solar One.

A letter (see Appendix 1) detailing the intended reliability objectives was sent prior to the visit. For future visits, a structured interview form should be used, and the lifetime estimates and repair statistics charts should be sent with the letter to allow the contractor to fill in estimates completely and thoughtfully.

II. SRCC Program

A. Program structure.
A weakness in the SRCC OG300 program structure is the lack of mechanisms for communicating field experience. There are three manufacturers sitting on the SRCC board, which certainly helps infuse some practical experience into basic policy formulation and interpretations. However, these manufacturers know only their own systems and may not follow up on field problems. An opinion voiced by several contractors was that their suppliers were really interested only in marketing more product, particularly collectors, and did not adequately focus on system problems experienced in the field. Without exception, those involved in the design review team do not have strong background in installation or servicing of recent SHWS systems. (Only George Lof has any significant field experience, and that is not recent.) Also, the standards committee (Wood, Darby, Peebles, Huggins, and Burch) lacks field experience. Lastly, valuable field experience is not adequately communicated amongst installers, with firms too often individually struggling to find solutions to the same problems.

Some suggestions toward solving these problems that were discussed and seem workable are:

X. **Establish mechanisms to feed field experience into the design review team and standards committee.** Four means were suggested. First, assemble and integrate on an ongoing basis the evolving technical briefs and bullets into the evolving "Manual of Practices" (MOP), specifically for use by the design review team. Second, work with the larger chapters to set up a committee that would review and comment directly to the standards committee on the SRCC system designs being installed in their area. Third, the local chapter committees should review the MOP on regular basis (e.g., annually) for completeness and accuracy. Fourth, the standards committee should bring in contractors into their conference calls for both specific and general comment.

X. **Provide for field feedback at SRCC board meetings.** An experienced installer should occasionally relay field experience to the board on important, relevant field issues. This could be done at the semi-annual meetings and/or the board conference calls. At board meetings the representative would be from the area of the board meeting, thus minimizing travel and changing with each meeting. It was proposed also that before meeting with the board, the field representative would meet with the local SEIA chapter members to reach consensus on issues to present to the board; this would broaden perspective and minimize biases. From the SRCC perspective, active participation of contractors would help SEIA members become more aware of the structure and benefits of SRCC. .

X. **Establish channels of communication for field experience amongst SEIA members themselves.** CALSEIA is publishing a technical column in each newsletter, highlighting a particular issue. These columns can be edited, enhanced, and distributed by SRCC to all SEIA chapters for newsletter distribution. SRCC should begin to assemble these and other technical briefs. All rating organizations (e.g., FSEC) and research participants (e.g., universities and NREL) should be aware that when an important practical design, installation, or maintenance item is uncovered, it should be written into a technical brief for distribution in the same channels. A periodic call for "problem reporting" through the chapters might be a good mechanism also.

B. OG300 guidelines.
There were instances where components are installed in the SMUD program in violation of OEM guidelines (vertical shafts on pumps, lack of tempering valve thermal trap, and possibly use of EPDM collectors under glazing). **How rigorously should SRCC enforce the OG300 principle (with design review particulars) of following OEM guidelines?** [The board has recently affirmed strict adherence to this principle, with allowance for the manufacturer to justify exception.]

A check valve is sometimes specified in the cold line leading to the mixing valve at the system outlet, to prevent hot water flowing back through the check valve and "heating" the cold water. Two contractors reported this experience, leading them to *always* use this precaution. A good thermal trap would also suffice, if naturally present or by design. In most Sacramento homes, the hot water lines enter the home at floor level, and a trap naturally exists. **Should there be an OG300 principle or design review practice requiring design prevention of or attention in the installation manual to convective feeding through the mixing valve into the cold water distribution system?**

III. Failure distributions

To determine "in service" failure distributions, one must have: 1) a "base population" of systems, whose size and system type distribution is known; and 2) accessible repair records that would identify failures as a function of system age. For systems before the SMUD program began, this will be difficult. In about half the cases, the repair records are not realistically available. In most cases, there would be significant uncertainty in knowing what the base population was. Many referrals come for repair on systems the contractor did not install (e.g. yellow pages, referrals), so the base is unknown, and we cannot use the repair data bases in a quantitative sense. Potential data sources with reliable base populations are detailed in Appendix 2. For SMUD's systems, only infant mortality and installation problem statistics would be available.

Contractors were queried as to their experience on lifetimes of the failed components they were fixing. The tables in Appendix 3 summarize their responses. Appendix 3a lists estimated mean lifetimes under "best case" conditions, i.e., water quality is good and the system is not oversized. Appendix 3b gives estimated lifetimes under "worst case" conditions, i.e., poor water quality and the system is oversized. These estimates can lead only to relative repair costs, as there is so much uncertainty. One contractor suggested asking for Afirst failures appear≅ and Amost will fail≅ data categories, rather than mean life. Appendix 3c provides self-reported service call numbers from those contractors that installed significant numbers of a specific system for which they were solely responsible. Systems installed under the SMUD program are at most 3 years old, and realistically only infant mortality rates could be inferred. In all cases, the data should be considered Alower limit≅, due to abandoned systems, system failures that the homeowner is unaware of, and the inherent biases of contractors, conscious and unconscious.

IV. Field experience

General

As one contractor succinctly stated, the three determining factors in system reliability are high temperatures, water quality, and method of freeze protection. High temperatures cause pumps and tanks to fail prematurely, and exacerbate the overall affects of poor water quality. Poor water quality inevitably leads to early pump and tank failure, negatively affects all valves, and will cause collector failure in open loop systems (usually seen as freeze damage). It is clear that unprotected systems WILL freeze in the mild Sacramento climate, albeit only once every several years.

Pumps

X. Keeping pumps cool. In both solar and tank circulation loops, the pump should be installed at the coolest place in the loop to prolong lifetime. Some SRCC systems do not follow this practice. For example, in an indirect system, the solar loop pump should be downstream of the heat exchanger, and the potable loop pump (if present) should be upstream of the heat exchanger. This is because pump life is inversely correlated with operating temperature.

X. Design and sizing Several contractors noted that pumps are replaced more often on Aoversized≅, selective surface systems, than in Asmall≅, non-selective surface systems.

X. Loss of fluid. In systems with small drainback tanks, the combination of large systems and a hot climate can cause high evaporation rates. (In general, anything causing such fluid loss is a problem, such as unreliable connectors on the tank.) With a dry tank or insufficient suction head (see next note), the pump will burnout, and numerous such pump failures due to the system affects were reported. Homeowner should be clearly and emphatically directed to check the water level in drainback systems.

X. Entrained air Pump failure can be caused by air in the glycol loop becoming trapped in the impeller cavity, leading to loss of suction and free-wheeling and burnout. (See glycol loop issues).

X. Suction head In drainback systems, careful attention should be paid to the head required on the suction side for proper starting. For example, the Grundfos series requires larger suction head for starting than the TACO pump. Some drainback manufacturers appear to place the pump immediately below the tank, and head may be insufficient.

X. Broken siphon loop Care should be taken in drainback systems with an inverted U-loop siphon from the tank to the pump. Any air entrapped in the U loop can cause failure to pump, and premature pump failure.

X. OEM guideline Grundfos pumps MUST be installed with shaft horizontal, as clearly shown by the manufacturers specification sheet.

∃. Grundfos versus TACO. No clear consensus emerged on one manufacturer versus another. One contractor claimed that the Grundfos pump has a carbon-steel shaft, which can wear, ride up the bearing sleeves, and "stick≅. The same contractor noted that he has replaced more Grundfos pumps than TACO, even though he personally installed 4 to 1 TACO versus Grundfos. An advantage of TACO is that the core+propeller unit is replaceable. Several other contractors felt Grundfos was more durable and the best pump choice.

X. *Avoiding conduit* The use of 24VAC pumps (Lang makes a series of these) will obviate need for conduit to the pump power.

Pressurized, closed loop systems

X. *Glycol and stagnation* SRCC must carefully consider the lifetime of the glycol under stagnation. For example, Dowfrost HD is four times more thermally stable than Dowfrost NT and is good for continuous service up to 325F, whereas Dowfront NT is good only up to 250F**. For selective surface systems, SRCC should consider mandating warnings to the homeowner about glycol degradation under stagnation.**

X. *Lessening the overheating problem* Lifetime of the glycol is increased when the collector is tilted to favor winter sun, versus summer sun. For larger systems, the homeowner can be encouraged to cover the collectors when going on an extended vacation to prevent stagnation damage of the glycol.

X. *Weather dependence of overheating* Damage to the glycol from stagnation is related to weather: the problem seems much more intense with clear summers in the west, versus the Acloudy summers≅ in the east.

X. *Installation guidelines* Air must be purged from the loop. SRCC should generate sound practices (there are several), and clearly forbid unsound practices (there are several!). Sources of information include the Hydronic Training materials, such as from I=B=R institute. For example, a consequence of air being left in the loop is that the pump can lose suction, freewheel and burn out (see pump); designs leaving the pump input/output ports horizontal will be potentially subject to this problem.

X. *Stagnation hot slugs* Solar loop cycling on the high temperature cutoff will send very high temperature slugs of solution into the system, causing expansion stresses and general degradation. This leads to premature component failure (tanks, pumps) and piping leaks. One solution is to run the pump power through a high-temperature snap switch located on the collector output, although this will force use of conduit up to the collector for 120VAC pumps and would prolong stagnation periods.

X. *Avoiding stagnation?* It may be possible to avoid summertime overheating when occupants are on vacation by suggesting to put the system on manual run for 24 hours. The system cooldown at night in many climates may be sufficient to prevent really cooking the system during the day. This needs study.

Solar loop regulation

X. *Code and rooftop PT* Code officials sometimes required P-T relief on the collector, even though such valves were located in the loop inside near the tanks and would adequately cover safety concerns. If installed on the collector outlet, this leads to unnecessary fluid dumping under high temperature conditions. One solution satisfying the building inspector is to place the required valve on the bottom header.

∃. *Pressure relief problem* In the case of the NEG ICS, there is a pressure relief at 75-80 PSI on roof, and setting on the pressure regulator on the hot water mains inlet into the system is crucial (can have up to 100 psi in the line). One contractor detailed a service call prompted by "frequent water on roof" that was caused by the regulator being set Atoo near≅ the pressure relief point.

Another problem experienced is that when the pressure reducer is on the hot water system inlet only, the cold (at potentially higher pressure than the pressure relief) will often bleed through the common Aone-armed≅ mixing faucet fixtures, pressurize the hot water side, and set off the pressure relief in short, repeated bursts.

X. *Air vent failure, solution* One contractor claimed that air vent valves have near 100% failure in 5 years: will leak, loose fluid from the pressurized loop. On pressurized loop systems, the valve is intended only for air venting during and immediately after filling. One solution is to fill both supply and return piping full, with an installed T at the high point open during fill to vent the air and detect when both lines are full. A brass plug is inserted when full. In general, failures of air vent valves is seen as a real maintenance problem by most contractors. Several contractors insisted air vent valves were unnecessary, if air is properly purged from the system initially.

X. *Air venting and stagnation problem* For glycol systems, solar fluid may boil under "no load" circumstances. If present, an air vent valve may release fluid vapor, and/or the pressure relief (set at low value of 50 psi on one system type) may exhaust fluid, leading to low fluid levels and potential vapor-lock.

X. *Flow meters?* Flow indication, measurement or adjustment is not required for SRCC installations. Due to particular site variances, it is inevitable that flow rates frequently different significantly from the SRCC assumption. Also, how often does Astuff≅ (e.g., copper plugs from header holes, blobs of solder) block passageways? A flow meter would indicate such problems. A plastic ball-float flow meter (rotometer) installed in the line was said by one contractor to be a cheap and reliable solution, with no reported breakage. [A strainer in the loop was considered by the same contractor worthwhile to prevent some of the potential flow blocking.] A negative with flow meters is that, according to some, they will eventually leak.

X. *Expansion tank orientation* There was some disagreement on "proper orientation" of expansion tanks: should these be installed upright, horizontal, or up-side down? One contractor pointed out that in glycol loops it is impossible to purge the air unless in upside-down configuration; this is made clear in general hydraulic training. Is there any advantage to pure nitrogen charge of the tank, for bladder lifetime and flexibility, as suggested by one contractor?

X. *Expansion tank sizing* It is unclear that the expansion tanks being installed have sufficient capacity for long piping runs. Neither solar manufacturers nor SRCC has rules relating the minimum size of the expansion tank to length of pipe run for glycol systems. All manufacturers of expansion tanks have tables relating the volume of expansion tank to the volume of fluid in the system. SRCC should obtain these tables.

X. *Sensor wiring* When mounting freeze snap-switch with wires directly entering the casing, care should be taken to relieve stress on and prevent excess motion of the wires, which can lead to stress breakage of the lead wires at the sensor body.

X. *Sensor wiring* Stainless steel clamps on sensor wire can short the sensor loop, leading to 24 hour pump operation.

X. *Sensor wiring* Only stranded, UV-protected sensor wire should be used. Telephone wire or bell wire will fail.

∃. *Sensor line pickup* One contractor reported a rapid pump cycling problem, that was determined to be due to electrical pickup from a nearby radio transmitter. The problem was solved by using shielded wire for sensor lines. The shield should be grounded at only one end, probably at the controller.

X. *Temperature probe failure* One contractor reported 5 failures, 4 in the field, of the temperature probes (2) now supplied by Heliodyne.

Storage Tanks

X. *Recovery capacity* Consumers must clearly understand the limitations and appropriate use of the Rheem tank. (On any one-tank systems with small electrically-heated volumes, the homeowners will experience reduced quantities of hot water during cloudy periods.) Sales personnel and installation personnel both should attempt to not distort the potential for "runout" of hot water. Misunderstanding causes frequent, costly returns for explanation that "nothing is wrong". Second, there are some improvements that the installer can make. The solutions include: a) install a larger element (5 and 6kW elements are available, although care must be taken to assure code regulations for wire size at that draw are met), turning up the thermostat (e.g., 150F), and rotating the existing element downward to affect a larger volume of water. This latter "measure" raises an unresolved question as to stress weakening and element failure, although the contractor claims no elements have failed. No element failures have been observed associated with this practice.

X. *Rheem tank failures* The Rheem tank quality was a problem for all contractors using the tank. Early on, 1 in 5 to 1 in 10 tanks suffered leaks on the collector loop wrap-around plumbing. Later tanks seem much better, as Rheem apparently identified the problem as poor solder joint at the end of the wrap around section. Installers beware. Rheem tank plastic drain fitting frequently leaks, especially at higher line pressures (which can be 100 psi in the Sacramento area). There is a sensor well in the side the Rheem tank, with threaded plug insert from the factory. It is significantly increased and unnecessary labor and hardware cost to remove the plug and insert an immersion thermometer. Metal strapping on the plug nipple is much quicker, cause less reliability problem, and is sufficiently accurate.

X. *Tripping the safety shutoff* Use of the Atank bottom≅ sensor for high-temperature cutoff is a potential problem. When this is set too near 180F, there is clearly potential for tripping the Ahigh temperature safety shutoff≅ (apparently at 180F) on tanks with an auxiliary element. The problem also exists potentially with two-tank systems after the system has saturated and a large draw is very quickly taken (e.g., summer vacation return). One contractor suggested that there should be some way for the safety reset to trip only when power is applied, to distinguish runaway elements (its job) and a hot solar tank (not its job).

X. *Modularity* Manufacturers should "modularize" the tank, heat exchange, pumping and controls, rather than asking the installer to do so, in the shop or in the field (see research suggestions below). If the manufacturer delivers pieces, they are best assembled in the shop.

X. *Dip tube problem* Dip tubes are too frequently "unattached" or missing; also, it can become unattached when thermosiphon nipples are installed. The dip tube should be checked before field installation (where solution is a major chore); removing the element allows good observation of the tube. When the dip tube is not properly present, the user may experience cool water, even when the tank is fully charged.

X. *Expansion tank?* Should storage tanks have an expansion tank if a pressure reducer is used on the supply? The thermal expansion can cause small fractures, leading to rust and leaks.

∃. *Anode rods* It appears that anode rods are never checked or replaced. Should this be a scheduled maintenance item?

X. *Forbid fiberglass* Never use fiberglass storage tanks; several contractors said that resins in the material leach out at higher temperatures, raise pH, and cause leaks in copper piping.

Tempering valves

X. Failure modes Tempering valve failure or sticking is a major maintenance headache, with mean lifetime perhaps as little as 3 or 4 years. Many times, the valve is "stuck" in the "cold open" condition (due to scale building up or "blobs" in the line?), and can be fixed by simply removing, cleaning, and exercising the spring mechanism. The spring will corrode and break, or become so clotted with scale as to be inoperable. The repair is easy if the system design has allowed isolation of the valve, and can be a major headache if not.

X. Thermal trap ***The Watts tempering valve is required to have a thermal trap: this is seldom done.*** Is this the reason for such high failure rates (see appendix 3c)? One contractor claimed to have installed about 100 valves since 1986 *with a thermal trap in place, with not one call yet due to mixing valve failure.* (He was also using the SPARCO valve, rather than the more popular Watts brand. Three contractors recommended the SPARCO product over the Watts.) The SPARCO aquamix does not specify thermal trapping. If problems are caused by scaling at the high tank-top temperature levels that will be experienced with no thermal trapping, it is not clear that changing manufacturers will eliminate the problem.

X. *Tempering vs. anti-scald.* The Watts tempering valve is very clearly stated by the manufacturer to not be an "anti-scalding device"; it is for capacity and energy conservation only. How does this relate to SRCC allowing that device for that purpose?

X. *Calibration problem* One series of the Watts tempering valve had a calibration problem: the setting was from 80 to 120F, not 120F to 160F. The solution was to remove the mechanism, and adjust the stop placement. In setting the tempering valve position, direct measurement of water temperature (after running for several minutes) is recommended to catch miscalibration problems before they turn into a return visit.

X. *Sensor placement* When the mixing valve is between the solar system and the storage tank (as it is on many systems), it is very useful to place the solar outlet temperature probe downstream from the mixing valve, so that mixing valve failure is immediately evident. It is also useful to install valves to isolate the mixing valve for its frequent repair.

X. *Soldering damage* It is imperative to remove the mechanism for tempering valve regulation from the unit before the unit is sweated into place. The high soldering temperature (non-lead solder) may be one cause of premature failure. When the mechanism cannot be removed, threaded units should be bought, with some provision (wet cloth?) for keeping the mechanism cool when the nearby joints are soldered.

X. *Hot-cold feedthrough* Tempering valves can cause feed-through between hot/cold lines, especially in larger buildings with large hot water recirculation loops, as the pressures will generally not be equal on hot/cold side of the valve.

Water quality

X. *Corrosion* Corrosion can be an *acute* problem in well-water sites, where water quality is not controlled. Municipal water suppliers frequently add lime to water to decrease corrosion potential, which concomitantly increases scaling tendency. Practices vary dramatically. Water used for closed drainback loops that is acidic should be neutralized or it will eat piping.

X. *Scaling* Scaling is often a problem is some locales; two contractors identified the area around Davis as high scaling. In such cases, certain system designs will be a problem. Open loop recirculation systems or draindown systems will have collector scaling (a disaster). Closed loop systems will have scaling at the heat exchanger, which will require regular maintenance. In shell-tube designs, the potable water side should be in the tube side, to allow de-scaling maintenance.

X. *Scaling* Larger, hotter-running systems should have more scaling problems than smaller, cooler-running systems. It might be beneficial in hard water areas to set the high-temperature cutoff lower than usual, although guidelines are unclear. Passive systems have uncontrolled summer temps which will routinely cause P-T valve relief under no-load conditions. Besides leading to valve failure (P-T valves are not meant to cycle), scaling will be promoted. A high percentage of scale-clogged HX on an older freon system type were repaired by one contractor, probably related to high temperatures at this point

X. *Bio-fouling* High Mn and Fe content along with high temperatures promote a reddish "bio-fouling", that was observed to totally clot the header of a drainback system. Photographs were shown of this.

X. *Flushing solder flux* Solder flux not properly flushed out will cause acidic closed loop fluid, and corrosion enhancement. **Should this be required as part of the manufacturer's installation instructions for closed loop systems**?

Freeze protection

X. *Recirculation failures* Recirculation systems will freeze on pump failure and on power failure. Freeze problems are observed in multiple collector array systems with recirculation freeze protection, when the controller and pump appear quite functional. It may be due to scaling in some tubes, or flow imbalance in arrays, with "starved" risers at particular locations. Recirculation freeze protection in large arrays is therefore considered questionable.

X. *Drainback failures* In drainback, sensor and controller failure can lead to frozen collectors. In severe climates, failure of the air vent valve to open causes draining to be too slow, and freezing can occur.

X. *EPDM?* Some contractors claim EPDM collectors can be routinely frozen, others claim only limited cycles of freezing before a leak can develop.

Piping

X. *Polybutylene* Polybutylene pipe will burst if routinely freeze-cycled, as evidenced from repair of solar swimming pool systems with such piping that were not drained in winter.

X. *Insulation materials* SRCC should have a table of available piping insulation materials with maximum operating and short-term temperatures. Temperatures differ significantly by system design.

X. *UV protection* Piping protection is best done with aluminum foil tape with special adhesive, as it is less labor-intensive than two coats of UV-inhibiting paint, and lasts longer. Job sites show the tape in good shape after ten years of exposure. Some contractors thought painting was altogether unsatisfactory. Those who felt paint was adequate emphasized the need for two brushed-on (NOT sprayed) coats, and use of semi-gloss, light colors (flat black, e.g., gave reduced lifetime on the painting). .

∃. *Insulation installation* Piping insulation will shrink slightly. In installing piping insulation, the installer should longitudinally compress the insulation to prevent separation at the joints in the insulation sections, upon shrinking.

X. *Soft copper rolls?* One contractor thought using soft copper piping in long rolls to/from the collector was best, to simplify installation and to avoid joints in collector loop piping. Other contractors assert that soft copper should not be used, to avoid air pockets in glycol systems and problems with draining in drainback/down, and to avoid erosion wear-out and leaking.

Miscellaneous

X. *Roof leaks* One contractor stated that roof leaks are common on wooden shake shingles, especially older, less flexible wood. His solution was to use flat metal gutter flashing around each penetration, about 1 ft2, to stop leaks through induced cracks. Caulking applied after the wood screw is set is worthless; fill pilot hole with caulk initially. [Note: another contractor says that when the wood screw is properly set into a joist rafter and caulked before screwing, leaks are rare. In fact, he said, use of flashing can cause tears in the tar paper, which is what blocks water in the first place, not the shingles.]

X. *Re-roofing hassles* Suggestions for collector roof installation methods that would not require removal of system for re-roofing would be very useful. A number of systems are simply removed at re-roofing, as the roofing contractors do not feel comfortable re-installing the systems.

X. *Servicing contract* A servicing contract is highly desirable item to keep systems properly operating.

X. *System diagnostics and service* It is a good idea to maintain a customer data base, and send out directions yearly to turn the auxiliary heater off during good summertime conditions. Water run-out alerts the homeowner to turn it back on in the fall. This leads to increased homeowner awareness of system failure (and increased repair business!).

X. *Shop testing* Should pre-assemble and pressure test in the shop/factory as much of the system as possible.

X. *Creep* An interesting observation: what causes absorber plates held on by crimping/clipping to creep *up* toward the upper header? One contractor claimed the creep was due to injection of cold water when the collector is at stagnation conditions; this causes the upper part of the riser tube to contract more rapidly than the fin, causing the fin to creep up the tube when equilibrium is re-established.

X. *Manufacturer newsletter* Manufacturers and major distributors should be encouraged to distribute a quarterly newsletter detailing problems and solutions.

X.*Manufacturer training* Training for installation at the manufacturer would be highly desirable.

V. Research/RFP suggestions

The topic most frequently mentioned was the tank-heat exchanger combination. A public domain, cheap, long-lasting solution would be a major contribution. The Rheem wrap-around tank has captured the market by default. This product is considered too costly, and subjects the industry to capricious price increases.

The development of integrated, packaged systems from manufacturer/supplier is highly desirable to increase reliability and reduce installation cost. A locally-available, common-size tank with standard system components (HX, pump, controller) in an attractive cabinet and with minimized connections (collector sensor, 4 piping connections, and element if one-tank)) should be available. A locally-available, common-size tank with standard system components (HX, pump, controller) in an attractive cabinet and with minimized connections (collector sensor, 4 piping connections, and element if one-tank) should be available.

All glycol systems, most ICS, thermosiphon systems have overheating problems under no load circumstances. Work is needed to devise solutions. One contractor suggested thermochromic films for stagnation protection.

Other topics:
a) Independent Energy recently introduced an "OR if Tlow >Tset2" lockout on heating element. How much could this save, and what is the optimal setting for Tset2?
b) Is 24 hour operation a good strategy for avoiding summertime overheating when occupants are on vacation?
c) Can a reliable draindown valve be developed?

Appendix 2
Data Sources for Failure Data

One contractor had a base of 2000 systems of the same type that were "inherited" from the business's predecessor, who installed them all in one sub-division in the early 1980's. A data-base of the original addresses exists, although not in electronic form. These clients could be identified by address, and the repair history on that subdivision tracked. These were all draindown systems, and there was a very high failure rate for the draindown valve. We could possibly determine the current fraction of "abandoned" systems (suspected to be significant, given the high cost of servicing these systems) with a phone survey. An issue is that these systems are not representative of current systems, and the results on repair of draindown valve (approx. 900 replacements!) are of little direct interest. Results for tanks and pumps might be nonetheless of value. Pump failure due to blocked draindown valve may be difficult to "remove" from pump failure data of more general interest. Cost of obtaining the data may be high, as these records are not separated from all repairs.

One contractor pointed out that Sears and Roebuck marketed the ASK/Daystar system, and may have kept good records on installation numbers and warranty calls. Staff will pursue this possibility.

One contractor has an installed base of about 400 of a single type of system since 1990 (Solahart thermosiphon), with clear records separating these repairs from other repairs. These data would then give fairly definitive "early" failure rates about the components of that system. More broadly, it was felt that servicing, repair, and warranty claims are being carefully tracked by the manufacturer/distributor in California, and which would broadening the base and time duration, perhaps back to 1985 on the SMUD system. The tank failure rates can be tracked back probably further yet, as the same **type** of the tank was installed since 1980 or so. This opportunity will be pursued in more detail, to give us the experience of obtaining failure data in a favorable context.

As a source of repair data, CALSEIA has maintained an 800 number for service referrals, and tax credit system installations. It may be possible to follow up on these leads.

Appendix 3a

Component Mean Lifetime[1] Estimates

Table for "BEST CASE" conditions: well-maintained, good water quality, and properly sized systems (lower operating temperatures)

Component	**Low[2]**	**High[3]**	
Collector			
Glass cover	30	60	
Polycarbonate cover	5	20	
Plastic films (Tedlar)	5	20	
Copper absorber	20	60	
EPDM absorber	5	20	
Glycol fluid	5	10	
Gaskets	?	?	
Tanks			
Glass-lined	8	25	
Polypropylene (unpress.)	20	40	
Pumps	5	20	
Controller			
Current models	10	30	
Sensors	10	20	
Loop regulation			
Mixing valve, no trap	3	7	
Mixing valve, trapped		5	30
Check valves	10	40	
Vent valve	3	8	
Vacuum relief		3	10
Draindown valve	3	9	
Expansion tank	5	20	
Pressure relief valve	10	25	
Pipe insulation			
painted	2	8	
aluminum tape	8	10	

1) Mean lifetime: Defined as the time for 50% of the population of operating units to fail.
2) Low: lowest estimate provided by contractors.
3) High: highest estimate provided by contractors.

Appendix 3b

Component Mean Lifetime[1] Estimates

Table for "WORST CASE" conditions: poor water quality and aggressively sized systems (higher operating temperatures)

Component Name	Low[2]	High[3]	
Collectors			
Glass cover	30	60	
Polycarbonate cover	5	20	
Plastic films (Tedlar)	5	20	
Copper absorber	10	30	
EPDM absorber	5	20	
Glycol fluid	3	6	
Gaskets	?	?	
Tanks			
Glass-lined	5	20	
Polypropylene (unpress.)	10	20	
Pumps	3	10	
Controller			
Current models	10	30	
Sensors	10	20	
Loop regulation			
Mixing valve, no trap	2	5	
Mixing valve, trapped		5	10
Check valves	5	10	
Vent valve	2	6	
Vacuum relief		2	6
Draindown valve	2	6	
Expansion tank	2	6	
Pressure relief valve	4	12	
Pipe insulation			
painted	2	8	
aluminum tape	8	10	

1) Mean lifetime: Defined as the time for 50% of the population of operating units to fail.
2) Low: lowest estimate provided by contractors.
3) High: highest estimate provided by contractors.

Appendix 3c

Self-reported Cumulative Service Call Numbers[1)]
Sacramento Area Contractors

Contractor #[0)]	1	2	3	4
base # systems[2)]/avg. years[3)]	125/1.5	2000/11	500/4	350/2
System type	Glycol	Draindown	Film ICS	Drainback
Cause for Service Call:				
Collector glazing	0	?	30[5)]	0
Absorber	0	800[9)]	na	0
Tank	1	25	na	2
Pumps	0	350	na	2[8)]
Controller	0	200	na	1
Loop regulation				
Mixing valve, no trap	3	400	?	2
Mixing valve, trapped	na	na	na	na
Check valves	0	na	na	0
P-T relief valve	?[7)]	?	na	1
Vent valve	na[4)]	some	?	na
Vacuum relief	na	many	?	na
Draindown valve	na	850	na	na
Expansion tank	0	na	na	0
Temperature probe leak	5	na	na	0
Piping	0	20	2[6)]	0
Homeowner education				
One-tank recovery	3	0	0	?

0) An arbitrary number for discussion reference only, has no relation to contractor list in text.
1) Total number of service calls reported for the entire base of systems.
2) The total number of systems in a given, well-defined base of systems for which the contractor is solely responsible.
3) The average age of the systems in the base; for SMUD program systems, the number is less than three, and roughly indicates the time history of activity.
4) Stopped installing them on systems, used brass T w/plug for filling.
5) About 25 damaged glazing films replaced from "trees, rocks..."; and about 1% seam failure on the early stainless steel model.
6) Pipes burst under unusually low temperature event and no use by occupants.
7) Had some trouble on other systems with P-T on collectors when required. Need to be placed on inlet header, not outlet.
8) Early design of drainback tank caused some leaking, which led to dry tank and 2 pump failures.
9) Extreme freeze damage, failed vacuum relief and/or draindown valve.

Appendix 3c, cont.

Self-reported Cumulative Service Call Numbers[1]
Sacramento Area Contractors

Contractor #[0]	5	6	7	8	9
base # systems[2]/avg. years[3]	350/1.5	100/5	500/4	200/1.5	250/2
System type	Glycol	Drainback	Thermosiphon	Glycol	ICS[12]
Cause for Service Call:					
Collector glazing	0	?	1	0	few[13]
Absorber	0	0	0	0	na
Tanks	20[5]	few[9]	?0	40[10]	na
Pumps	2	0?	na	0	25
Controller	0	?	na	0	12[14]
Loop regulation					
Mixing valve, no trap	45[6]	0[11]	?	2	60
Mixing valve, trapped	na	0[8]	na	na	0
Check valves	0	some	?	0	0
P-T relief valve	0	?	?	0	?
Vent valve	na	?	?	?	na
Vacuum relief	na	?	na	?	na
Drainback valve	na	na	na	na	na
Expansion tank	0	0	na	0	0
Temperature probe leak	5	na	?	0	0
Flow meter break/leak	na	0	na	na	na
Piping	many[4]	?		0	0
Homeowner education					
One-tank recovery	?many?	0	?	?	
Programmatic	130[7]				

0) An arbitrary number for discussion reference only, has no relation to contractor list in text.
1) Total number of service calls reported for the entire base of systems.
2) The total number of systems in a given, well-defined base of systems for which the contractor is solely responsible.
3) The average age of the systems in the base; for SMUD program systems, the number is less than three, and roughly indicates the time history of activity.
4) Experienced leaks with charge/fill hose bibs (Arrowhead 254cc), leading to loss of loop pressure. Homeowner would call if P<10psi. Re-tightening of these bibs was found required to prevent leaking. Changed to MATCO boiler drain, and the problem solved.
5) Many failures (about 25/350) (early on especially) with the Rheem tank, especially the heat exchanger leaking at the bottom or top fittings. Although most found in the shop, about 20 have failed in the field, usually in the first week of operation.

6) Apparently mostly due to a calibration problem on the WATTS valve, experienced by other installers also. Some problems with "too much cold", stuck in cold on position. Now uses the SPARCO mixing valve, no reported problems yet.
7) OG300 design review apparently OK'd no high limit setting, whereas SMUD required it, not discovered until 130 had been installed. An unfortunate SNAFU.
8) Also uses the SPARCO mixing valve, not the WATTS.
9) Polypropylene tank. Some early problems with the weld, material seems to last indefinitely.
10) High collector loop leak rate on Rheem tank, early on. Most rejected in the shop.
11) Many repairs reported, but not on the installed based of this type of system which has a thermal trap between tank outlet and mixing valve.
12) ICS unit with hybrid pump added on later to help in overheating problems.
13) Several tubes were observed to be broken, probably vandalism.
14) Thermal snap switch, set to 160F, replacements.

Manufacturing Support Initiative and Solar Development Project

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Solar Weatherization Assistance Program
Post Installation System Inspections

Introduction

The intent of the SWAP program was to provide solar water heating systems - and their ensuing energy and monetary savings - to low-income clients. The systems have in large part achieved - and continue to achieve - these goals.

The systems listed below were installed during the SWAP program that was conducted throughout Florida from 1994 through 1997. This listing provides information on the condition of these systems during inspections conducted between 2002 and 2004. The primary purpose of the inspection was to determine the operational status and condition of the systems.

Overall, the majority of inspected systems are still working. The clients are in large part quite satisfied with their systems. Nevertheless, this inspection project has revealed numerous items that need to be considered in future solar programs.

Lessons learned

Some basic lessons learned are as follows:

1. Systems should be kept as simple as possible. Certain systems that require client interaction are not recommended for this type of program. This suggestion has been strongly considered and implemented in the current Front Porch Sunshine program.

2. Solar systems require periodic inspections and maintenance. The more complex the system (complex being more components) the more this applies. A large majority of problems were related to a variety of valves that required service and or replacement. The majority of low-income clients will not (cannot) expend funds to have systems maintained or components replaced even though the maintenance or repair charges are relatively minimal.

3. Agencies promoting and funding low-income solar programs should set aside funds for future maintenance and repairs. Otherwise their investments in these systems will be for naught once a component fails and the client isolates the solar system. Even if they do not fail, certain components have a set lifetime and should be replaced prior to that period.

4. A number of collectors were discovered to have failed, both flat plate and Integral Collector Storage (ICS). Contact with the flat plate manufacturer indicated that the majority of these failures were caused by a poor header/riser connection design which has now been resolved. The ICS manufacturer in turn had received some absorber materials that were not manufactured properly and led to leakage problems. During the standard warranty period, the manufacturers provided coverage for replacement or repair of

defective absorbers. Unfortunately, many low-income clients did not contact anyone, but simply shut the system down whenever a problem occurred. Once the standard warranty period expired and the limited warranty took affect, the clients were then responsible for the labor portion of repairs. Because of this burden, once again many clients chose to deactivate the system instead of paying for labor charges. In many cases, the local weatherization agency used other funding sources to cover the labor fee for the clients. In other cases, the local weatherization agency informed the client that the SWAP program had terminated and that there was nothing they could do.

5. Exterior pipe insulation (and insulation coatings) was a major problem. Exterior insulation, due to the harsh external environments, requires periodic maintenance and recoating or replacement. It was discovered that in cases where the installers affixed metal foil tape over the piping insulation, the insulation was still intact. It is recommended that metal foil tape be used in future low-income solar programs – as well as in general installations.

6. A large number of air vents were observed to have either failed by leaking, or having the exhaust port sealed by scaling. Air vents are extremely susceptible to sedimentary scaling – especially in areas where water chemistry are ideal for this condition. Scaling buildup eventually seals the air vent's exhaust orifice and also appears to affect the internal mechanism, leading to leaking air vents.

7. Problems with freeze valves led many clients to isolate their collector loop and therefore sacrifice the use of a solar system. These valves are used to prevent freeze damage in soar collectors. Their lifetime appears to be in the seven to ten year range and should at least inspected and /or replaced before this period. ICS systems would preclude the use of these valves if the correct piping and pipe insulation were used. This plastic bodied valve also incorporates a section of metal that was observed to have been rusting severely in many instances.

8. Anti-scald valves, while beneficially providing scald protection in the active pumped systems – especially where older and very young persons reside - were very susceptible to scale buildup within the internal parts of the valve. A large number of valves were stuck at a certain setting. This did not affect the performance of the valve – at that setting – but instead precluded any future adjustment. (Note that the clients had been informed to exercise the valve periodically, but in reality, people do not have the inclination to do this.) Discussions with weatherization personnel in Miami indicated that many of these valves had developed problems and had to be repaired. In most cases, the valves were eliminated from the systems.

9. Other than a few instances, the various controllers used proved to be quite reliably. Differential controllers had a few problems, but overall, the majority of theses controllers and their associated sensors appeared to have functioned quite reliably. The photovoltaic controllers appear to be the most reliable of the control methods used. Unfortunately, this was not the case with the timer controllers. Once again, the timer is a component that needs periodic client attention (periodically checking the set times and replacing the

batteries). Inspections revealed that few timer systems were still working. In addition, clients had not periodically checked their timer or the timer's backup battery.

10. Installation craftsmanship, in many cases, left much to be desired. Although all systems were installed by Florida licensed contractors, the knowledge of system installation methods and trade skills - as well as use of industry standard practices and material - varied widely from installer to installer. This was quite evident in all aspects of the installations - sealing of roof penetrations, securing sensor wiring, use of rust resistance materials, etc. Membership in the solar industry needs to be looked at as a professional trade – with it's required skills – versus a cause.

11. Water heater failure was observed in numerous installations. These were conventional water heaters that, although part of the overall solar system, are also components that are required for heating water regardless of whether there is a solar system at the residence or not. Therefore, the water heaters cannot be seen as a "solar" component that has failed but instead as part of the overall water heating system. The majority of failures were due to leaks in the water heater – either from the internal tank of from fitting joints at the top of the tanks. When water heaters failed, the person or company replacing the water heater did not reconnect the solar system. It appears that neither the client nor those replacing the water heater understood the significance of the solar system.

12. FSEC will use the findings of this inspection process in administering the technical aspects of the state mandated system approval process. This investigation of long term occurrences related to solar systems and their installations provides solid evidence and factual information on issues that have previously been somewhat controversial and argumentative since no solid long term affect evidence had been physical observed or acquired.

13. Overall, most clients did not have any problems with having a solar system. A few even understood what the function of the system was and that it saved them money. Others were completely ignorant of the system and had to be informed what the "skylight" on the roof was for. A more thorough education program needs to be conducted with future low-income programs. Also, those receiving solar systems should have a commitment to that system. In turn, funding agencies should implement some type of long term maintenance program.

Table 1 lists the number of instances discrepancies and notable negatives were identified during the inspection process – per system – per 179 systems.

Item	**Instances**
Insulation	60
Air vent	30
Collector	28
Freeze prevention valve	26
Sealing	23

Anti-scald valve	22
Wiring (exterior)	16
Tank (water heater)	15
Control	12
Mounting (collector)	12
Pressure relief valve	11
Piping (exterior)	11
Flashing (exterior)	8
Piping (interior)	8
Isolation valve	6
Insulation (interior)	6
Pump	6
Ceiling penetration	6
Wiring (interior)	5
Sensor (exterior)	2
Check valve	2
Drain valve	2
Disconnected (for unknown reasons)	2

Table 1

Site listings

Listed below are textual descriptions of each inspected system.

Sites are listed below by various SWAP program geographical areas. These are defined as:

CENTRO: Arcadia, Clewiston, Immokalee, La Belle, Moore Haven, and Okeechobee.
CENTRAL: Gainesville
CITRUS: Crystal River, Dunnellon, Floral City, Homosassa, Homosassa Springs, and Inverness
LEE: Ft. Myers, No.Ft. Myers, and Lehigh Acres.
MID FLORIDA: Brooksville, Bushnell, Spring Hill, Webster, and Wildwood.
DADE: Florida City, Goulds, Homestead, Leisure City, Miami, Naranja, Opa Locka, Perrine, and Richmond Heights.

Systems are identified as follows:

ICS = Integral collector storage system.
Diff = Active direct systems using a flat plate collector and differential controller.
PV = Active direct systems using a flat plate collector and photovoltaic controller.
Timer = Active direct systems using a flat plate collector and timer controller.

A web site has been developed that provides the same information listed below and numerous photographs of the various sites. This web site will be for review by selected parties, including the recipients of this report, but will not be made available for general viewing. The web site can be accessed at:

http://www.fsec.ucf.edu/solar/projects/inspections/inspectionsitesall.htm

In addition, a spreadsheet listing all sites and identifying specific problem items noted during the inspections is included at the end of this report and at the following web site:

http://www.fsec.ucf.edu/solar/projects/inspections/FinalInspectionSpreadsheet.pdf

CENTRO

Site 795
System type: Pumped - differential control
Installed:1996
Inspected: 2003
System is not working.
Control problem.
Test with controller tester indicated no response for either differential or high limit.
Anti scald valve on 4.
Collector feed pump line unsecured.
Collector feed is from bottom of tank. This line should have been clamped to tank, etc.
Tank area piping not insulated.
Minor leak at feed line isolation valve joint. Appears to have calcified.
Sensor wire in tank area hanging loose. Not properly secured.
Sloppy exterior pipe flashing.
Freeze valve exhaust point is almost touching roof surface.
Exterior insulation is degrading. Exterior pipe runs not very secure.
Excess exterior sensor wiring has not been secured.

Site 800
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System running continuously.
Controller was set on "On" setting. Continuously running pump.
Set to "Auto" and pump went off.
Control tester indicated that all functions were operating properly. Sensor readings were reasonable.
Cold feed plumbed into collector return line.
Water stains in utility room ceiling where collector loop piping penetrates ceiling. Result of water entry via roof flashing? (Roof flashing and sealing appears intact.)
Controller attached to wall over utility room door. Hard to access.

Tank area piping sporadically insulated.
Collector feed line from bottom of tank (and that includes pump, etc.) is not well secured.
Exterior insulation is degrading. Some portions are covered with foil material. Those appear to be intact.
Sections of copper piping are not insulated.
Collector mounting strut attachment screws rusting.
Freeze valve exhaust nozzle is touching the roof.
Metal parts of freeze valve are starting to rust.
Sloppy roof pipe flashing.
Sensor wiring has cracks in some areas.
Air vent exhaust port is sealed due to calcification.
Exterior sensor lead/sensor wiring connectors directly exposed to environment.
Electrical tape used to secure insulation. Has degraded and lost adhesion.

Site 801
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System is not working.
Control problem.
The solar system was disconnected (plumbing) several months ago and a new tank installed due to tank leak.
The controller was still plugged in. Wiring from the pump to controller was removed.
Client stated that the system was not working.
Tested controller with controller tester. Failed high limit and differential test.

Site 802
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System is working.
Controller tester indicates differential and high Limit work.
A/S valve stuck at 4.
Cold in is plumbed into collector return line.
Rust at tank top fittings.
Sloppy ceiling penetrations for collector feed/return piping.
Escutcheons could have been used.
Evidence of leak at collector feed line drain bib (calcification).
Unsecured excess sensor wiring at tank.
Sloppy exterior pipe flashing.
Exterior pipe run is not secured.
Exterior insulation is degrading. Piping exposed due to deteriorating insulation.
Excess sensor wiring is not properly secured. Exterior of wiring is deteriorating.
Air vent exhaust port is sealed with calcification.
Pressure relief valve exhaust shows indication of water calcification from past operation.
Sensor wire flashing is not turned down to prevent water from entering flashing.

Site 803
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System not working
Control problem.
120V to controller is ok. Registers at 120V at electrical outlet. Does not register at controller. Power light on controller was off.
Turned controller to "On" selection and nothing happened.
Insect residue in controller body at sensor terminals.
Anti scald valve stuck on 4.
CPVC used as tank T/P relief valve outlet line.
Cold feed plumbed into collector return line.
Sensor wiring at tank area unsecured.
Evidence of some type of leak at tank drain fitting. Water residue.
Exterior insulation is degrading.
Exterior sensor lead/sensor wiring connectors directly exposed to environment.
Excess exterior sensor wiring is not secured.
Metal parts on freeze valve show extreme rust deterioration.
Air vent exhaust port is closed due to calcification.
Exterior piping is not secured.
Collector sensor wiring connections exposed to environment.
Sloppy exterior pipe flashing.

Site 804
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
The system is working fine. Controller tester indicated that all functions were operational. Sensor readings were reasonable. All components are in satisfactory condition. Client understands what the system does and realizes savings that are accrued.

Site 805
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System working fine.
Controller tester indicated differential and high limit were working.
Interior:
Water heater is in kitchen. Neat and clean installation.
Anti scald valve is stuck
Components and insulation in good condition.
Exterior:
Pipe clamps used to secure long pipe run on roof and on exterior wall of house.
Exterior roof insulation is degrading, leaving visible copper piping.
Insulation coating on side of house runs is in relatively good shape.

Comparing side of house insulation (protected from sun) and roof insulation shows the effect of UV on components.
Section of roof piping is not insulated – insulation could have degraded completely and fallen away.
Air vent port is just about clogged due to calcification.
Collector mounting screws are rusting.
Metal part on freeze valve is starting to rust.
Gaps between copper piping and insulation in vertical pipe sections at roof provide opening for water penetration.

Site 807
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System is working. Client shows an interest in system.
Controller tester indicated that high limit and differential worked fine.
Client had leaks at tank area fittings. Solar company came out several years ago and "did something." Leaks continued. Called solar company again. Did not come out. Leaked stopped. (Appears that leak stopped because of calcification at joints.)
Interior:
Controller is dangling from one screw. Installer used screw without sinker to mount in drywall. Controller has minor insect residue inside body.
Piping is not well insulated at tank. Splits, etc.
Sensor wiring (tank and collector) is hanging loose. Not secured.
Anti-scald valve is stuck at 3.
Cold feed line is plumbed into collector return line.
Exterior:
Minor leak at collector feed fitting at collector. Evidence of water accumulation from drips below this area.
Exterior insulation is degrading.
Air vent clogged – port has calcification. No vent cap.
Sensor wiring (tank and collector) is hanging loose. Not secured.
Piping coming off the roof and down side of building is not secured with clamps.

Site 808
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 Operation unknown.
No one lives at this residence. House has been gutted and appears to be in the remodeling phase. Collector still on roof. Note very loose control wiring.

Site 811
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System is working.
Tested controller with controller tester. Differential and High Limit tests passed.

Client stated that they did not get enough hot water. I readjusted the lower element to mid range. Was set on lowest.
Interior:
A/S valve stuck on 4.
Bottom feed – top return. Cold inlet plumbed into return line.
Exterior:
Exterior insulation deteriorating.
Collector feed line on roof is not insulated.
Sensor line flashing entry point is exposed to elements. Can allow water into sensor wire flashing opening.
Air vent port is closed - calcified.
Sensor wiring loose and not UV protected.
Freeze valve outlet port is against roof shingle.
Pine tree leaves accumulation at top of collector. Less than ½" space under collector.
Collector enclosure screws are rusting.

Site 812
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
Yes according to resident, but undetermined.
Owner states that system appears to be working. Would not allow access to tank. Owner had to leave. Asked her to check to see if light was on at controller. Yes, as far as "power on" light.

Client had to remove failed anti scald valve several years ago. Took valve out completely. Roof is in terrible shape. Owner will re-roof and take collector down. Will put it back up after reroofing.
Exterior insulation deteriorating.
Sensor wiring loose.

Site 814
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
Operation unknown. Unable to contact client.
No flow through collector loop during time external part of system was inspected.
Exterior:
Collector mounted on shade overhang above door. Rust from metal roof has dripped upon collector glazing and left rust stains.
Collector feed/return piped to rear of house along side walls. Total was 70 feet of pipe run (for each – 70' feed, 70' return).
Collector mount may have created some type of leak onto wood below. Stained.
Exterior insulation is deteriorating.
Doubtful that system works. No one home. Terrible odor coming from under front door.

Site 815
System type: ICS
Installed: 1996
Inspected: 2003
System is working fine. Good installation.
All interior system piping is well insulated.
Excellent exterior insulation UV protection. Durable foil material used over insulation.

Site 816
System type: ICS
Installed: 1996
Inspected: 2003 No system at site. (Was an ICS.)
Original client no longer lives there. Neighbor informed me that the residence has seen two occupants since Fisher. House has new roof. Imagine that ICS unit was removed for re-roofing and not reinstalled.

Site 817
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System is working. Checked controller out, worked fine. Client's son was explained how system works. He is familiar with plumbing, etc.
Interior
Anti scald valve stuck.
Well-maintained environment.
Installer should have secured feed line (coming from tank bottom - with pump) so that it was more secure – against tank.
Tank area piping insulated.
Could have secured some of the sensor wire a bit better. Some dangling.
Ceiling penetrations could have used escutcheons.
Exterior
Exterior insulation wrapped with metal foil tape. Still intact.
Flashing work leaves something to be desired – aesthetics wise. But appears to be functional. Roof tar used at flashing appears to be cracking somewhat.
Sensor wire flashing pipe opening could allow rain penetration. Should have been better sealed.

Site 821
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 Interior
Leak at fittings (feed line pump and isolation valve).
Sensor wiring unsecured. Draped over pipes.
Exterior
Freeze valve was dripping small amount of water.
Excess sensor wiring not secured.

Sensor lead/sensor wiring terminal is unsecured and exposed to environment.
Insulation is deteriorating.
Air vent port is sealed due to calcification.
Metal parts in freeze valve are rusting.

Site 822
System type: Pumped - differential control
Installed: 1996
Inspected: 2003 System is working.
Interior
Pump piping run was loose. From bottom feed. Pump stuck out and was accessible to people passing. Pump body was very hot.
A/S valve stuck.
Sensor wiring not secured.
Exterior
Exterior insulation degrading.
Sensor wiring exposed and cracking.
Screws attaching struts to collector are rusted.
Air vent port is locked - calcified.
Body of freeze valve appears to be deteriorating - metal parts.

Site 823
Installed: Jun 96
Inspected: Mar 03
System is not working.

System was isolated. Collector sensor was disconnected. Major leak at pump area. Now calcified. Evidence of pipe leak above the tank. Plug for electric water heater indicates some type of flash burn.
Plugged pump into 110V receptacle. Did not come on. Major problems with this system. Poor elderly client has no hot water. Told her to call local WAP agency. Needs electrical fixed.
Interior
Leaks at copper piping bend.
Water stain at ceiling at pipe penetrations.
Residue of major leak at pump.
Electric outlet for water heater has been fried.
Water heater appears to be in bad condition. Someone has taken plates off water heater – top and bottom. Client states that her nephew was looking into water heater/electrical problem but never came back.
Anti scald valve stuck.
Exterior
Insulation starting to degrade.
Gaps in insulation in pipe runs exposing copper piping.
Screws used to mount struts to collector are rusting.
Long pipe runs lying on roof allow leaves to accumulate.

Flashing entry for sensor wiring is open and will allow rain to pass down through opening.
Section of sensor wiring is not secured.
Metal foil tape securing insulation is losing adhesion.

Site 824
Installed: 1996
Inspected: 2003 System is not working.
Pump problem.
Pump is defective.
Controller was set on Auto. Pump operation indicator was on. Pump was plugged to controller. No hum, no vibration, no heat. Plugged pump directly into 100V receptacle. Pump did not come on. Pump area indicated residue from previous leak.
Leak at fitting below return ball valve/check valve.
Interior
Leak at pipe fittings.
Anti scald valve was stuck.
Exterior
Gaps between copper piping and insulation in vertical pipe sections at roof provide opening for water penetration. Especially at bends where pipe runs go from horizontal to vertical. Insulation has deteriorated at bends and exposed piping.
Long pipe runs lying on roof allow leaves to accumulate.
Screws used to mount struts to collector are rusting.
Air vent is in good shape. No calcification at outlet port – as is often the case.

Site 825
Installed: 1996
Inspected: 2003
System operation is operating. It is strongly suspected that flow in the collector loop (perhaps including the water heater plumbing) is restricted due to extreme mineral scale build up.
Interior
Anti scald valve was stuck.
Insect residue in controller enclosure.
Evidence of drip from the drain valve in the collector feed line. A solidified chunk of mineral was coming from the drain valve port. Suspect there could have been a very minimal leak that eventually calcified.
Exterior
Section of pipe near ceiling penetration is not insulated. Escutcheons should have been used.
Insulation protected by foil tape. Some sections of foil tape are losing their adhesion and coming off.
Sealing of pipe flashing and collector mounts with roof tar like material was done pretty sloppily.
Air vent outlet port is becoming calcified.
Long sections of sensor wiring is not secured.

Site 827
System type: ICS
Installed: 1996
Inspected: 2003 System is fine yet client complained that there was not enough hot water.
System problem: Inspection revealed that the inlet three-way valve was turned so that cold feed water went directly to the electric tank.
Corrected this and now the client has use of the solar system
Client stated that the water heater had been replaced several years ago. The tank was replaced and the plumbing to the ICS unit was reconnected to the water heater. Perhaps the plumber turned the valve in the wrong position. It is rather confusing. When in the solar loop position, the handle is in a horizontal position. Most people would assume that this cuts off flow to the ICS unit. This is the reason some type of tag connected to the valve would help. The valve handle has arrows showing flow, but homeowners are not familiar with this.
Interior
Inspection revealed that the inlet three-way valve was turned so that cold feed water went directly to the electric tank.
Well-insulated tank area piping.
Escutcheons could have been used at ceiling penetrations.
Exterior
Exterior insulation is well protected with foil type material.
Pressure relief valve handle is starting to rust.

Site 828
System type: ICS
Installed: 1996
Inspected: 2003 System working fine. Occupants very happy to have system.
Interior
All system piping is well insulated.
Exterior
Exterior insulation is well protected with foil type material.
Flat roof. There was evidence of water damage on utility room ceiling where the ICS feed and return lines penetrate the ceiling. Client stated that these were there before the solar system was installed. Had roof repaired prior to solar installation. Solar system roof flashing is well done. No leaks from solar system.

Site 830
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
No one home. Phone number no longer for former resident. Stopped several times. No one ever home. Left note and card.
Exterior
Exterior insulation deteriorating.
Sensor wire flashing access is open to environment. Sensor wiring loose.

Site 837
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System is not working.
Controller defective. Tested controller with manufacturer's tester. Failed all modes.
Controller body was completely covered with insect residue. Controller had come loose from the wall and was placed atop system pump.
Interior
A/S valve stuck at 4 setting.
Tank fittings starting to rust. Especially the bottom port/solar fitting.
Cold feed plumbed into collector return line.
Water stains in utility room ceiling where collector loop piping penetrates ceiling. Result of water entry via roof flashing? Roof flashing and sealing appears intact.
Exterior
Freeze valve installed with exhaust tip against roof shingle. Touching roof.
Metal exterior portion of freeze valve is rusting very badly.
Collector sensor stretched taunt coming out of roof flashing.
Exterior senor wiring not secured or UV protected. Sensor/wiring leads connector should have been secured and protected from environment.
Exterior insulation covered with foil material. Insulation and foil material are still intact.
Small portion of exterior copper piping is exposed where insulation shrank or piping was not insulated from start.
Water stains in utility room ceiling where collector loop piping penetrates ceiling. Result of water entry via roof flashing? Roof flashing and sealing appears intact.

CENTRAL AREA

Site 343
System type: ICS system
Installed: 1996
Inspected: 2003
System no longer operating.
Collector feed and return lines disconnected from collector.
Owner states that a leak developed in the collector several years ago. Did not want to spend funds to have repaired.

Site 345
System type: ICS system
Installed: 1996
Inspected: 2003
System no longer operating.

The absorber was completely removed from the collector. Client was unavailable but it is assumed that a problem occurred with the absorber which was removed and for some reason not reinstalled. Collector enclosure showed evidence of internal leaking.

Site 348
System type: ICS system
Installed: 1996
Inspected: 2003
Uncertain as to operation of system. Client not available.
Note the section of rust on the metal roof below the collector - it appears that there may have been a leak in the absorber.

Site 351
System type: ICS system
Installed: 1996
Inspected: 2003
Not operating properly.
Leak in the absorber. A constant drip was seen coming from the bottom left corner of the enclosure.

Site 361
System type: ICS system
Installed: 1997
Inspected: 2003
Clients not available. Appears to be operational. New roof covering was added since collector was installed. Appears that roofing was installed with collector still attached to roof.

Site 370
System type: ICS system
Installed: 1996
Inspected: 2003
Client not available. System appears to be operational.
Note long pipe run and accumulation of leaves against piping.
Insulation is deteriorating.

Site 658
System type: ICS system
Installed: 1997
Inspected: 2003
House unoccupied for about 1 year (per neighbor). Neighbor stated that previous owner had informed him that the system was working fine. Current operation unknown.
Note vent used to route collector piping. Does not prevent rain penetration.

Site 659
System type: ICS system

Installed: 1997
Inspected: 2003
Residence has been unoccupied for some time.

<u>CITRUS COUNTY AREA</u>

Site 1

System type: ICS system
Installed: 1996
Inspected: 2002
System has had no problems at all. In good condition. Installer will have to be contracted to remove collector for reproofing. Roofer will not touch it. Provided client with installer's contact information.

Site 3
System type: ICS system
Installed: Sep 96
Inspected: Nov 02
System is working. No problems.
No problem with system. Client satisfied.

Site 4
System type: ICS system
Installed: 1996
Inspected: 2002
No problem with their system since installed.
System is in working condition. Roof insulation was painted. Appears to have been repainted since system was installed. Owner very happy. Notices the savings. Has plenty of hot water.

Site 5
System type: ICS system
Installed: 1996
Inspected: 2002
No problem with their system since installed.
Roof insulation was painted. Appears to have been repainted since system was installed.
Very happy. Notices the savings. Has plenty of hot water.

Site 7
System type: ICS system.
Installed: 1996
Inspected: 2002
System not operating.
New owner installed new water heater and did not connect plumbing to solar system.
When the new owner purchased the house (in Spring 2001), the collector loop was

isolated. When the collector loop was opened, the owner noticed that water was coming off the roof. The new owner stated that it initially appeared that one of the valves was leaking. Upon closer investigation, he noticed that the leak was also coming from inside the collector. The landlord took the glazing off the unit and noted that there were numerous and severe leaks at the absorber's end caps. (Note that the ICS manufacturer has stated that he did have a bad batch of end caps, which caused failures on about 6 units. They were all covered by warranty.) At that point the owner decided to just isolate the system.

Site 34
System type: ICS system
Installed: 1996
Inspected: 2002
System not working.
Per owner, two years after system was installed it developed a leak. Client claims leak was at outlet piping area. (Could have been inside the collector as well.) Minimal water dripped in attic. Suspect water leaked between return line piping and outer insulation. In any event the major problem was that the well pump ran continuously because of the leak. Client claims the well pump eventually failed due to overuse. Claims he had to purchase a new one for $500. Client isolated the system via system isolation valves at the water heater. Has no interest in trying to determine what the leak was and having the system fixed. Would not allow me on the roof. Client was done with the system. Client should have followed up with installer to get system fixed.

Site 36
System type: ICS system
Installed: 1996
Inspected: 2002
System is currently working fine.
Had to replace the absorber approximately 2 years ago. Appears that there was a leak in the absorber. Running down the roof from the enclosure. Solar installer came out and did the replacement. No charge. Warranty covered.

Site 37
System type: ICS system
Installed: 1995
Inspected: 2002
System working just fine.
Contacted client. Has not had any problems with the system. Client satisfied with system. Plenty of hot water.
Conducted system inspection. No problems. Exterior insulation deteriorating somewhat but still intact and serving its purpose.

Site 38
System type: ICS system
Installed: 1995

Inspected: 2003
ICS system is working. Leak in roof. Visible on inside sheathing/trusses at ground level in garage. Traced back to upper (2 ea penetration points) collector mounting area. Wood was used in attaching mounting clips to roof. Wood is cracked in half – possibly allowing water penetration. Homeowner has construction experience and sealed mounting areas with pitch. Added pitch around wood mounting blocks. Suggested that he add pitch over entire wood mounting block.
Exterior insulation is deteriorating. House is up for sale.

Site 42
System type: Pumped – differential controller
Installed: 1995
Inspected: 2002
System disconnected by owner.
System has been disconnected. New tank has been installed. Appears that the system was not providing enough hot water in winter months. Client is interested in perhaps using system again. Did not have any component problem with system. Felt they did not get enough hot water during winter months. Initial system tank may have been installed with lower element disconnected. Owner replaced the water heater and reattached solar plumbing. Will use in summer months. Provided advice regarding the setting of the elements and the trimming of trees on south side. Owner claims that all components appear to be in working order. Stopped by house as per arrangements made in Dec 02. No one home. Tried several times during day.

Site 44
System type: ICS system
Installed: 1995
Inspected: 2002
No problems whatsoever. Working fine. New owner. Stated that she did not know anything about the system. Nor did plumber she knows. Explained system to her and stated that I would mail her an owner's manual. Sent manual.

Site 46
System type: ICS system
Installed: 1996
Inspected: 2003
System is working. No major problems. Tank area piping should have been better insulated. Insulation missing from collector feed at roof. Wood used in attaching mounting clips to roof. Still structurally sound but weathering.

Site 47
System type: ICS system
Installed: 1996
Inspected: 2002
Freeze valve leaking. Client claims that he had to replace freeze valve about 2 months ago. Had handyman do the work. Was charged $20. This makes me suspect that it could

have been the pressure relief valve since freeze valves are about $40 in cost. Follow up: Client called me on Nov 02 stating that water had been running off the roof. The client isolated the system. Having taken pictures of the collector and associated plumbing I could visualize and ask the client specific questions about where the system was leaking. I had the client open the valves sending water back to the collector. I then instructed the client to go look at the collector from ground level. I then asked the client to tell me exactly where the water was coming from. (Note that I was able to instruct the client what to look for since I had the photograph.) The water was coming from the freeze valve. Told the client to isolate the system and that I would come by in a few weeks and determine the exact problem. Pretty certain it is the freeze valve.
Dec 02 Visit to site. Ambient temperature was in the 70s. Owner had isolated solar loop. Opened solar loop and discovered that freeze valve was dribbling water. Provided client with a new freeze valve. Added Teflon tape and instructed client on how to replace valve. No ladder to get on roof at the time. Client did not want me on his roof. Insurance concerns. Client is mechanically inclined and will replace the valve.

Site 51
System type: ICS system
Installed: 1995
Inspected: 2002
No problem with their system since installed. Quite pleased.

Site 58
System type: ICS system
Installed: 1996
Inspected: 2002

System working just fine
Owner never had any problems with system. Very happy with system. Can see the savings. Plenty of hot water. Conducted system inspection. No problems. Insulation not deteriorated. Condensation under glazing. Evidence of freeze valve activity. Rusty water. Wood mounting blocks still structurally sound. Instructed clients to cut some of the oak tree branches that create some shade in the afternoon. Also, branches need cutting to protect roof shingles. Left business card in the event she has questions in the future.

Site 773
System type: ICS system
Installed: 1996
Inspected: 2003
System is working. No problems. New owner. Did not know anything about the system. Inspection revealed no problems. Valve handles were positioned correctly. Exterior insulation still in good condition. Used latex paint. Wood supports at collector mount are being affected by the environment but are still functional. Explained system function to homeowner. Will send manual.

LEE COUNTY

Site 374
System type: ICS system
Installed: 1997
Inspected: 2004
Unknown.
Inspector was unable to make contact with the client. Conducted several visits and also checked the local directory to no avail.
The collector is still mounted to the roof. The wood mounting blocks below the mounting surface clamps are starting to deteriorate.

Site 375
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System appeared to be working.
The tank, controller and pump are all within a wooden enclosure located next to the residence. The enclosure was very dirty, exhibited rat droppings, and had a terrible smell.
The controller appeared to be working.
The electrical to the water heater and controller appears to have been modified. The supply electrical to the water heater was 120V (should be 240V) on AWG 12 (should be AWG 10).

Site 377
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is working fine.
Controller tested with manufacturer's tester and passed all functions. Sensor readings were reasonable. Pump operational.
The collector looked very good. Surprisingly, the freeze valve and air vent were in very good condition. The installer did not use the manufacturer's collector mounting clips. Instead, a simple bracket was used to attach the standoff to the collector enclosure. Several of the screws used were not stainless and are thus starting to rust.
The exterior pipe insulation is starting to severely degrade. Some type of painted coating was used instead of metallic foil tape.
The exposed pipe runs were rather long and could easily have been plumbed inside the attic.

Site 381
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System no longer connected.
Water heating was replaced and solar system was not reconnected.

Collector was still installed on roof. (Collector is shaded during afternoon hours.) Controller was still attached to wall. Test of controller indicated that it was still in working condition.

Site 383

System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is still working as installed.
Doubtful, efficiency wise. Bottom feed - bottom return strategy used on installed 40-gallon water heater that is mounted on a shelf in the garage. Unless the bottom feed – return plumbing has internal and separate tubes for the feed and return lines, this system could be recirculation water solely in the collector loop line and bypassing the water heater.
The controller and sensors test indicated that there were no problems with the controller and sensors. Sensors gave reasonable measurements. Controller was checked with manufacturer's controller tester.
The collector and mounting look good. Installer used short external runs for the piping - ideal. External insulation is well protected with metallic tape.

Site 387
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is no longer operating.
Pipes in the flat plate collector split during a freeze in 1998. Client indicated 2-4 tubes had burst. The client had the installer try to repair it, unsuccessfully, since the piping started leaking again. The system was then isolated. Eventually the water heater was replaced and the system plumbing was disconnected completely and all interior system components removed. All that remains is the solar system is the collector still mounted to the south side of the house. Interesting mounting location.

Site 389
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is still operating.
Differential controller and sensor test indicated no problems.
Ceiling penetration poorly done.
Collector is in good condition. Note leaves accumulation at collector and piping.
Exterior insulation is still intact but deteriorating. Sections of insulation protected with metal foil tape are in relatively good condition.
Air vent exhaust is becoming clogged. Freeze valve exhaust is too close to the roof.

Site 390
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is working fine.
Controller and sensors are functional.
Sections of exterior pipe insulation protected with metal foil tape are sill intact. Sections protected only with paint type coating are deteriorating.
Note leaf accumulation along piping and collector.
Air vent exhaust clogged with water sediment buildup.
Collector bracket mounting screws are starting to rust.

Site 391
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
Unable to contact client. Collector is still installed on roof. Freeze valve is leaking.

Site 392
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
The system is no longer operating.
The solar collector is no longer on the roof. The house is currently undergoing extensive modifications, including a new roof. Unable to make contact with client. Not listed in directory. Reason for removing he collector is unknown. Collector is not at ground level or in external storage room.

Site 393
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
The system is still operating.
Controller and sensor tests were positive. Controller tester indicated that the "freeze" control was defective.
The freeze valve is dripping and metal body components of valve are rusting.
The air vent exhibits a tremendous amount of scale build up and the valve exhaust is clogged with scale buildup.
Exterior insulation that was protected with foil tape is still intact. Other sections that were protected with paint type coatings are degrading.
Roof is in poor condition.

Site 395
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004

System is still operating.
Test of controller and sensors were positive.
Anti scald valve is leaking and stuck at set position.
Very unusual plumbing strategy. The return from the collector feeds into the cold water supply at tank just before the anti scald valve. All plumbing was ¾" copper except for a short piece of ½" copper in the hot water line to the house. Plumbing was very poorly installed. The electrical switch to the water heater was installed backwards.
The freeze valve and air vent were leaking. Metal parts of the freeze valve were severely rusted. The exterior piping was insulated but the hot return was not wrapped with aluminum foil tape and therefore starting to degrade.

Site 396
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is still operating.
Conducted test of controller and sensors – no problems.
Defective pump had been replaced in 1996 by FSEC staff during installation inspection.
Exterior insulation is deteriorating. Exposed piping gaps in insulation.
Insulation that was protected with metal foil tape is in good condition. Sections protected with paint type coating are deteriorating.
Air vent is clogged. Freeze valve exhaust is too close to roof..

Site 652
System type: ICS system
Installed: 1997
Inspected: 2004
System is still operating.
The solar collector is mounted facing north on a north facing roof. The roof has a very low slope. The angle is only about 5-degrees so the collector does receive solar radiation. Client states (via telephone) that the system is still operating. Unable to get into house since client did not come to the site at designated time. Contacted the person who had replaced the water heater and was told that he had replumbed the new heater to the collector loop.

Site 653
System type: ICS system
Installed: 1997
Inspected: 2004
The system is working although one discrepancy is critical.
This was a very poorly installed system. The wood collector mounting bracket supports on the roof has deteriorated and allowed the collector to start sliding down the roof. The unit was not mounted properly. The collector is now at an angle to the roof line because one end has slipped. The collector feed and return plumbing lines hold the other end. The collector is now lying almost directly upon the roof. It is anticipated that during weather conditions of high winds and rain, the collector could slide further down the roof. The

result could be that the piping can no longer hold the collector and finally give way and that the unit would fall off the roof. The current situation creates a safety hazard. Steps have been initiated to current this problem as soon as possible since the collector is directly above a side door.
The ICS unit also exhibited a large amount of internal condensation as well as severe mould and detritus build up on the external glazing. It is suspected that a large tree may have abutted the house and was cut down some time in the past. This could have created shade thus resulting in the mold buildup on the glazing. Also note the water marks on ceiling from possible leaks from roof flashing.

Site 655
System type: ICS System
Installed: 1996
Inspected: 2004
Unknown.
Inspector was unable to make contact with the client.
The collector is still mounted to the roof. The wood mounting blocks are starting to deteriorate and split. The collector is coming loose from the mounting and slipping down the roof (one or two inches at this time).

A water heater was placed along the side of the road suggesting that this was the residence's old water heater. Whether the solar system was reconnected to the new replacement water heater remains unknown.

Site 656
System type: ICS system
Installed: 1997
Inspected: 2004
System is still operational. Client states no problems have been encountered with the system. Client is very pleased with the system. Client is also aware of what exactly the system does.

Site 850
System type: ICS system
Installed: 1997
Inspected: 2004
System no longer working.
Original clients are no longer at this house. Current occupant knew nothing about the system.
Inspection revealed that the glass had been removed from the collector and laid back on the frame without the secure glazing cap frame wall. A safety hazard since the glazing could have blown off during periods of high winds. FSEC staff purchased some screws and secured the glazing to the frame wall glazing cap. Before doing this it was noted that one of the tubes must have developed a pinhole leak and that the former client must have tried sealing the hole with some type of sealant material. Undoubtedly this failed and the

collector was then isolated at the conventional tank location. The client cut the piping going to the collector and adjusted the isolation valves.
The wood mounting used in securing the collector to the roof is deteriorating. The installer must have used standard wood instead of exterior pressure treated wood. In any event, wood should not be used for collector mounting purposes. The ICS unit is now sitting directly upon the roof.
The exterior insulation appears to be in relatively good condition. Note the short plumbing run on the roof. Nails were used to hold the roof pipe penetration flashing. This is not a standard industry method and the nails also appear to be rusting.

Site 853
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004
System is no longer operating.
The air vent developed a constant leak and the client drained and isolated the system. Test of the controller and sensors was conducted. Tests indicated that the controller and sensors were still in operational condition. The pump was disconnected but appeared to operate when plugged into a receptacle.
The solar collector and glazing looked good. The rear mounting brackets at the collector only had one screw (which was rusted) rather than two.
The pipe insulation was coated with some type of paint material. The material degraded and in turn the insulation itself is also starting to degrade.

Site 858
System type: Pumped - differential controller
Installed: 1996
Inspected: 2004

The system is no longer operating.
The solar collector is no longer on the roof. The house is currently undergoing extensive modifications, including a new roof. Unable to make contact with client. Not listed in directory. Reason for removing he collector is unknown. Collector is not at ground level or in external storage room.

Site 864
System type: ICS system
Installed: 1997
Inspected: 2004
System is operational. Insulation is still in good condition. Client stated that he has not had any problems with system and is quite satisfied with it.

<u>MID FLORIDA</u>

Site 16
System type: ICS system

Installed: 1996
Inspected: 2003
System is working fine. Was an old monitoring site.

Site 17
System type: ICS system
Installed: 1996
Inspected: 2003
System is working fine.
No problems. System valving strategy is rather confusing. Noticed that client has attached hose to collector return line drain bib and uses this to fill washer. Exterior insulation is in good shape. Installer used some type of paint to coat the insulation. This works much better than the usual tape job.

Site 18
System type: ICS system
Installed: 1996
Inspected: 2003
No problem with system operation.
Exterior pipe insulation protective coating has somewhat degraded leaving raw insulation exposed in areas. Eventually, insulation itself will degrade.

Site 19

System type: ICS system
Installed: 1996
Inspected: 2003
System operating. Roof leak problem.

Appeared to be some type of water dripping on garage ceiling. Owner suspects that it is from solar system. Stated that she had called WAP agency that coordinated installation but was told there was nothing they could do since the program was terminated. Nevertheless, client is quite satisfied with the system but does not want to be burdened with maintenance and troubleshooting costs.
Indeed there was a water stain on the garage ceiling drywall. Measured location of stain and compared with location of water heater and piping. Went in attic and observed that there was a stain on the wood in the attic as well. Measured location of stain vis a vis identifiable materials and locations in attic (pipe penetrations, lag bolt trusses). Inspected the roof and noticed that there were small holes a few inches away from one of the collector mounting points. Following is only an assumption: These holes could have been the result of the installer attempting to locate the truss members during the installation of the collector. Not having located the truss member, the installer could have tried repeatedly to make contact with a drill bit. There are 8"s between the holes and the current location of the mounting bracket. This could have caused the numerous holes at this location. Or, these holes could have been caused by some other means. In any event, the inspector filled the holes up as best as he could with a readily available sealant

material. Informed the occupant's adult daughter that they would have to follow up with some better type of sealant. It appears that the husband had used some type of roof coating material on an adjacent workshop roof. I told the daughter to have her father do the same at the above noted location.

Site 20
System type: ICS system.
Installed: 1996
Inspected: 2003
No problem with system operation once valve position corrected.
Original client had moved. New owner did not know what solar system was all about. Explained system design and operation The system collector loop valves were turned to the wrong position - collector was isolated. Inspector corrected this. System is now working fine. Advised owner that water will have small air bubbles for next few days and then clear up. Owner was glad to know about the system. Will send ICS system owner's manual. As usual, the exterior insulation was deteriorating. In many cases such as this one, and others listed in the report, when the insulation deteriorates, it often leaves small sections of collector loop piping exposed. Duct tape used to cover insulation had also deteriorated.

Site 21
System type: ICS system.
Installed: 1996
Inspected: 2003
No problem with system operation.
Client confirmed that the system had not had any problems since installed. This was one of the monitored sites.

Site 401
System type: ICS
Installed: 1996
Inspected: 2003
System working fine. New owner did not know what system did. Inspector provided information and checked system. Tape used to hold insulation is deteriorating but insulation is in satisfactory condition. Hard to access system valves above elevated tank.

Site 413
System type: ICS system.
Installed: 1997
Inspected: 2003
No problems. Owner quite satisfied with the system.
Insulation in satisfactory condition.

Site 418
System type: Pumped - differential control
Installed: 1995

Inspected: 2003
System was not operating. Numerous leaks in collector at header/riser locations.
Client no longer lives there. Son now lives in house. Stated that system was great and that he had plenty of hot water, etc.
Could not get into storage room where water heater and pump/control/valves were located. (Wall to wall and floor to ceiling were covered with various stored materials.)
Inspected collector on roof and could see that the collector must have been isolated since there were numerous locations that indicated some type of water/leak activity at the header/rise connections.
Exterior insulation had deteriorated. Piping was exposed in large insulation material cracks. Air vent port calcified. Freeze valve not pointing down.

Site 422
System type: ICS
Installed: 1996
Inspected: 2003
No problems. The homeowner is pleased with the system.

Site 428
System type: ICS system
Installed: 1996
Inspected: 2003
System working fine after correcting valve positions.
New owner of the house. System was isolated (via isolation valves). Current tenant had isolated the system because he had noticed water coming out of the freeze valve in the winter. He isolated the system. Unfortunately, the freeze valve is supposed to open and release water intermittently during temperatures below 40 F. Inspector un-isolated system, and checked for collector and valve leaks. No leaks. Provided resident with instructions on how the system works (especially the freeze valve) and on anticipated savings.
Owner requested a system manual, which inspector will send.

Site 429
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System is not working.
New family at house. Developed collector leak about 2 years ago. Isolated system. Could not afford to have fixed. Turned collector loop isolation valves. Controller was left plugged in. (I unplugged.)
Leak is at header/riser connection. Leak created algae growth on roof.

Site 430
System type: ICS
Installed: 1997
Inspected: 2003

Glass broken and laying atop Teflon film
Family no longer lives there. Young person at the house knew nothing about solar system. Left card and note for parents to call me. Uncertain if system was still working or had been isolated. Broken glass is lying inside and at bottom end of ICS unit body. Inner Teflon film is still intact.
Exterior insulation is developing large cracks due to long term deterioration.
Butted ends of insulation have separated and piping is exposed.
Excellent collector mounting. Still secure and sealant is flexible.
Stopped again later that month. No one home. Left note and card on door.

Site 432
System type: ICS unit
Installed: 1995
Inspected: 2003
System is currently working.
Had serviced twice. Leaks from roof. 2 years ago. Client could not tell me where the leaks were from. Suspect that they were from valves – freeze or pressure relief.
Exterior insulation protective material is degrading. Duct tape used over insulation is disintegrating.

Site 438
System type: ICS
Installed: 1997
Inspected: 2003
ICS collector has no problem.
The freeze prevention valve is starting to leak. I told the resident to get it replaced. Said he would. Provided local contact.

Client is very happy with his system. Has three daughters and appreciates the solar system.
Insulation tape is deteriorating thereby allowing insulation to split open and expose copper piping at some locations.

Site 440
System type: ICS
Installed: 1995
Inspected: 2003
System is fine, but owner wants to keep it isolated during the time that the house is being remodeled. Tried to reason with the client that the system can be turned on even with the remodeling occurring, but client wouldn't listen.
Un-isolated the system and checked for leaks. No leaks in collector, piping, or valves.
Insulation tape is starting to deteriorate, but the insulation is in relatively good condition.

Site 443
System type: Pumped - differential control
Installed: 1995

Inspected: 2003
Uncertain about system operational status. No one home.
Clients moved many years ago. Neighbor stated that there have been three new occupants since then. House is in a flood lot and always gets flooded. Collector appeared to be in satisfactory condition. Could not get to tank. Left card on door advising new owner to contact me about the system.

Site 446
System type: ICS system
Installed: 1996
Inspected: 2003

System was working fine.
Exterior insulation was in reasonably good condition.

Site 452
System type: ICS unit
Installed: 1995
Inspected: 2003
Currently working.
Had serviced twice. Leaks from roof. 2 years ago. Client could not tell me where the leaks were from. Suspect that they were from valves – freeze or pressure relief.
Exterior insulation protective material is degrading. Duct tape used over insulation is disintegrating.

Site 453
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System was removed. Client had to re roof their house and did not want the collector reinstalled. Claimed that system had leak problems. Per sister.
Photos - when system was installed in 1996.

Site 454
System type: ICS
Installed: 1997
Inspected: 2003
No problems
Minimal insulation tape deterioration.
Auxiliary tank is in elevated position and system valves are above the tank. Valves are very hard to access.
Owner states there is plenty of hot water. Appreciates solar system.

Site 455
System type: ICS
Installed: 1997

Inspected: 2003
System is working.
Freeze valve starting to fail. I noticed that the freeze valve was dripping every so often. Informed client that the valve should be replaced. Provided name of local solar company. Tree does not obstruct solar window.

Site 458
System type: ICS system
Installed: 1996
Inspected: 2003
System is working just fine.
Owner is very happy and appreciated the inspection.

Site 460
System type: ICS system
Installed: 1997
Inspected: 2003
System is working fine.
Insulation joints (where taped) are coming apart and exposing copper piping.

Site 463
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System not working.
Freeze valve failed about six months ago. Side of valve appears to have leaked – as well as through normal orifice. Client tried fixing freeze valve leak with JB Weld but this did not work. He isolated the system. Collector does not appear to have any leaks.
Valve leak caused stain and possible damage to roof area.

Site 464
System type: Pumped – differential controller
Installed: 1996
Inspected: 2003
The system appears to be working. The client complained about very low water pressure at the sinks, bath, etc. I tested and this was so. Checked the valves at the tank area and noted that the cold service gate valve appeared to have a minor leak. Someone had previously wrapped the body of the valve in duct tape. I lifted the tank's pressure-temperature relief valve and noted that indeed, there was hardly any pressure.
The client stated that several months ago she had the solar system installer come back out and check this problem. It appears that nothing was done and she was going to call them back again. I advised here to get a local plumber which would be cheaper than having the solar installer come from Tampa. I suspect that there is a problem in her water supply line.
Tested controller with manufacturer tester. All fine. Sensor readings were reasonable.
The exterior insulation had degraded and copper piping was exposed. Sensor wiring was

exposed and had become quite brittle. The freeze valve was filled with mud from mud daubers. Valve body appeared worn and will eventually fail. The air vent still had its protective cap – which is something that was not evident in many other systems using air vents.
The solar collector looked fine. No leaks.

Site 468
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System is not working.
System developed leak in collector about two years ago. Owner could not afford to have service done on the system. Owner isolated the system (collector loop isolation valves). Inspection revealed leak at header/riser location. Also noted leak at air vent during inspection.
Owner liked her system, but claims she cannot afford the service call. Installer wanted $50 per hour.

Site 474
System type: ICS system
Installed: 1997
Inspected: 2003
System no longer at residence. System was removed.
The house has a new tenant. A new roof was installed on the residence. When this was done, the solar collector was removed and discarded. Current tenant did not know whether the system had had a problem or whether it was in the way of re-roofing. In any event the system is no longer there.

Site 475
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System not working.
In approximately Fall/Winter 2000, there was a leak in the area of the water heater. Suspect it was from valve fitting above the water heater. Water was dripping onto water heater and I assume rusting the fitting connection areas. Client only knew that there was a leak and that she called a plumber and had the tank replaced. The plumber replaced the water heater with a smaller unit (40 gal.) and appears to have re-plumbed the collector feed and return lines into the water heater. During the inspection, the inspector noted that the collector loop isolation valves were closed. The collector loop was bypassed. I also noted that the anti-scald valve had been left in the hot out line but that the cold in port had been plugged up. The valve was no longer receiving cold water for tempering purposes. Opened the isolation valves. I also opened the return drain port to make sure water was circulating. After about 20 seconds I heard water falling off the roof unto the ground. I went out and noted that there was a major leak in the solar collector. The leak appeared to be at a riser/header connection. It was a major burst. Without taking the

cover off, I was not able to determine exactly if the burst was at the riser/header connection or whether it was from a split tube.

I then went back downstairs and isolated the collector loop.

What was wrong with this system? This is the possible scenario.

1. The client said that she had called the solar installer some time after the solar system was installed. The reason for the call was not made clear to me. The client did not seem to remember. She did recall that the solar installer came out and told her that she would have to flush the system periodically. Connect a hose to the collector loop drain valves and flush it from there. (Comment: The client is elderly and although quite alert and intelligent, this is not something that a grandmother should not have to do!) I suspect that perhaps the installer may have even disconnected the anti-scald valve at this point. This could have been the problem that she called him for. Not enough hot water.

2. In any event, after this, there was a drip from one of the valves above the tank. This resulted in causing water to pool atop the water heater which in turn led to corrosion of the inlet and outlet ports atop the water heater. Or led to causing a hole atop the water heater that in turn let water into the body of the tank causing a tank leak, etc. In any event, this dripping valve led to an eventual leak. The client stated that she did not have a problem with water running off the roof at this time. Therefore, we can assume that the collector was fine.

3. Because of the above, the tank had to be replaced. The client stated that she could not contact the solar system installer and therefore called a plumber. The plumber replaced the water heater. At this point, it is unclear whether the previous solar serviceman disconnected the anti-scald valve from the cold service line or whether the plumber did. In any event, the anti scald valve was disconnected from the cold service line. (It could have been the anti-scald valve that was leaking at the fitting and therefore either the solar installer or plumber could have disconnected it.)

4. In regards to the collector leak, there are several possibilities.

a. It appears the plumber isolated the solar system when replacing the water heater. If the plumber had isolated the collector loop without draining the collector loop and a freeze occurred after that, a tube could have burst because of this. Especially if there was no water pressure available for the freeze valve to work.

b. The plumber could have replaced the water heater and reactivated the system. The absorber could have burst due to freeze damage for numerous reasons. Lack of operation of the freeze valve, no power, lack of pressure in the line, etc.

c. The collector could have developed a leak from a faulty joint. Only taking the collector apart could really determine the problem.

In any event, this solar system is inoperative. The client does not seem to understand the system operation and is not able to provide me with information that can help develop a chronology of what occurred. I was not able to get specific information related to whether the client knew that a problem had occurred with the collector and knew that water was running off the roof. All the client seemed to know was that the plumber told her she needed a new water heater.

Site 476
System type: ICS
Installed: 1997

Inspected: 2003
No problems.
Valves ok. Very small aqua colored spots on tube and end caps in area of end caps. Appears to be some type of residue from the brazing process? In any event, they do not appear to be getting larger and causing corrosive wear. Insulation is satisfactory. The usual – tape that holds the insulation is deteriorating somewhat. Auxiliary tank is in elevated position and system valves are above the tank. Very hard to get to and have to use mirror to determine orientation of valves.

Site 478
System type: ICS
Installed: 1996
Inspected: 2003
System is working.
Freeze valve failed several years ago. Replaced it with a drain valve. No problems since. House is currently for sale.

Site 479
System type: ICS system
Installed: 1996
Inspected: 2003
ICS system is working.
Freeze valve has a small drip that has stained the shingles on roof.
Insulation is deteriorating and cracking. UV protectant has faded. Will send client name and address of vendor that sells the freeze valve.

Site 484
System type: ICS system.
Installed: 1997
Inspected: 2003
No problems.

Site 486
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
No operational problems.
Client stated that when it was cloudy and raining, she did not have much hot water or, the water was not hot enough. She has called the WAP agency but they informed her that the program was over and that there was nothing they could do for her. I checked the water heater circuit breaker and sure enough, it was off. Since this elderly lady was alone, I also did a little maintenance on the exterior insulation and did a complete check-up on the system. All is working fine. Controller, pump, sensors, etc. Repaired severely deteriorating insulation. (Noticed that insects had built nests within controller enclosure box. Cleaned out. Somewhat common in some utility rooms.) Will probably need a new air vent and freeze valve within 2-5 years.

Site 488
System type: ICS system
Installed: 1996
Inspected: 2003
No operational problems.
Exterior pipe insulation protective coating is degrading. Duct tape was used and is disintegrating.

Site 491
System type: ICS system
Installed: 1995
Inspected: 2003
System is not working.
ICS is fine. Freeze valve is defective. Stared constantly leaking several years ago. Client called local agency that installed the system and was told to turn the isolation valves above the tank. This isolated the ICS unit from the auxiliary water heater. This occurred 2 years ago. Left the client – adult sibling – my card and told him to have his father call me. States that father was going to replace the auxiliary water heater in the near future. Doubts that he will re-plumb tank to solar system. Informed him that he should get a new freeze valve and keep the solar system.

Insulation tape is deteriorating.

Site 493

System type: Pumped - differential control (not an ICS as had been reported by agency)
Installed: 1996
Inspected: 2003
No longer operating. Collector taken down.
Had a pumped differential system. Roof was damaged during a storm several years ago. Collector was never replaced. Not sure if collector was damaged.
Checked the auxiliary tank area. Isolation valves were turned to isolation position. Controller was still plugged in. All three operating indicator lights were on. Unplugged the controller from the wall.

Site 495
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System removed. System had problems – leaks at collector – and client got rid of system. (Pictures are during initial installation.)

Site 496
System type: ICS system
Installed: 1996

Inspected: 2003
System is not working. ICS collector is fine. Freeze valve is defective.
Freeze valve developed constant leak. Client called local WAP agency that installed the system and were informed to turn the valves above the tank. This occurred 2 years ago. Unfortunately, the freeze valve is causing many of these systems to be isolated because the client's claim that they cannot afford to have someone come out and replace it. So, for a $50 part, a $2,000 system is being wasted.

Site 497
System type: ICS
Installed: 1996
Inspected: 2003
System is working fine. Inspection revealed no problems. Insulation is somewhat worn after all these years. Tape holding the insulation is failing.
Client is happy with the system.

Site 500
System type: ICS system
Installed: 1996
Inspected: 2003
No problem with system. Collector somewhat shaded.

Site 501

System type: ICS system
Installed: 1997
Inspected: 2003
No operational problems with system.
Insulation is deteriorating and gaps are evident between insulation sections. Long pipe run at this site. Lot of leaf accumulation against long pipe runs. Pressure relief valve lever is very rusted.

Site 505
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
No apparent problem with system.
Client claims that water heater TP valve leaked water into storage room and house. Had hose connected to TP valve drain in storage room. Tried TP valve and it operated quite well. Also shut off. Advised client to put a 5-gallon bucker under TP valve drain in the event valve was actuated in future. Also told to call plumber next time this happened. Client's son also claimed that water ran off the roof – continuously – from the freeze prevention valve and the air vent. Did not see any leaking during the inspection. Air vent had sediment build up at bleed outlet. Both the air vent and freeze valve will more than likely fail in due course.

Insulation was degrading. Duct tape was used as protective coating. The tape had also degraded.

Site 508
System type: ICS
Installed: 1997
Inspected: 2003
System is working fine.
No one was home. Neighbor came over. Stated that system is working fine. Asked how he knew that. He stated that owner had passed away and that he takes care of maintenance tasks for the owner's widow. Said that he is familiar with the system and the isolation valves above the tank. Told him that the freeze valve will eventually fail and that he should make sure that it is replaced instead of just isolating the system. He understood the purpose of the freeze valve.

Site 516
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System not working.
System is no longer working. Developed a leak on the roof about 1 year ago. Conducted inspection of the tank area components. Controller was still plugged in. On auto setting. Collector loop isolation valves were closed. (Isolated collector loop.) Opened valves and soon saw water coming from the roof. Investigated at roof and discovered that someone had cut the collector feed line at the roof and capped it off. Used a plastic cap that had cracked. This was the reason water was coming off the roof during the inspection.

Site 526
System type: ICS system.
Installed: 1997
Inspected: 2003
No operational problems. System works fine.
Duct tape used over exterior insulation is deteriorating and exposing copper piping.

Site 529
System type: Pumped – differential control
Installed: 1995
Inspected: 2003
System working.
The anti-scald valve was stuck and could not be turned to another position. Appears that the owner had attempted to adjust valve setting unsuccessfully.
When I manually set the controller to Off, the LEDs starting blinking uncontrollably – and a clicking noise was heard. Flicking the switch several times eliminated this occurrence.
At least ½ of the exterior pipe insulation had degraded to a point where there was no insulation and the copper piping was exposed. The sensor lead- sensor wire connection

was not well protected. The sensor wire flashing was no longer sealed to prevent water penetration.

Site 530
System type: ICS system
Installed: 1997
Inspected: 2003
System is working fine.
No problems. Exterior pipe insulation is in good shape. Tape used has resisted deterioration.

Site 532
System type: ICS system
Installed: Mar 97
Inspected: Feb 03
No problems with system. Client satisfied with system.

Site 533
System type: Pumped - differential control
Installed: 1995
Inspected: 2003
System is no longer operating. Collector developed a slow leak several months ago. Leak stared in approximately Jan 03. Client lived with it since leak just "dribbled a bit of water." Client is re-roofing the house and decided to take the collector down. Does not intend to reinstall the collector. Has taken the pump, controller, and motorized check valve off. The collector was in the yard and I was able to see where the leak was. Once again, like many other flat plate collectors that failed in this program, the leak was at a riser/header connection.

Site 535
System type: ICS system.
Installed: 1996
Inspected: 2003
System is working.
Storage tank installed outdoors with minimal protection. Rusting out and deteriorating. Will leak from bottom and rusty top areas within next 6 months.
Exterior insulation is cracking in some areas.

Site 538
System type: ICS system.
Installed: 1996
Inspected: 2003
No operational problems with system. Client states that she has lots of hot water and reduced electric bills.
Usual exterior pipe insulation degradation. Used duct tape that has deteriorated and left insulation exposed. Several large cracks in insulation allow water to penetrate to piping.

Site 693
System type: ICS
Installed: 1997
Inspected: 2003

System is working fine. Owner understands what the system does and is quite appreciative of it. She recently had the roof shingles replaced and insisted that the system stay on the house. Flashing was well done. The piping insulation needed a UV protective coating. Suggested that she use latex paint. Also some sections of roof pipe run copper were exposed. She will fix this. It was a real pleasure talking to someone that understood the function of her system and was appreciative of what the system provided – savings and plenty of hot water. The client also stated that she often turns the power to the auxiliary tank off and relies solely on what the ICS unit produces.

Site 695
System type: ICS
Installed: 1997
Inspected: 2003
System working fine. Inner Teflon glazing has come off the frame and is lying on bottom tube of unit. New owner understand the system. System manual came with house. Uses residence in winter months.
Owner goes away for the summer and leaves the system as is. Does not drain or isolate the collector loop. This undoubtedly creates extreme temperatures in the unit.

Site 698
System type: ICS system
Installed: 1997
Inspected: 2003
No operational problem.
Exterior pipe insulation is degrading.

Site 699
System type: ICS system
Installed: 1997
Inspected: 2003
No problem with system operation.
Tape used on exterior pipe insulation is degrading. Insulation is in pretty good shape.

Site 703
System type: ICS system
Installed: 1997
Inspected: 2003
No problems with system. Insulation tape deteriorating somewhat.

Site 704
System type: ICS system
Installed: 1997
Inspected: 2003
System is fine but is isolated. The client did not want the system because the local agency had told him that he would have to cut trees down. He came home one day and saw that the system was installed. Since he thought that the system would not work because he was not about to cut down his trees, he isolated the system and it has been that way since 1997. The ICS unit on the roof is covered in shade due to massive oak trees. I did un-isolate the system and noted that there were no leaks at the ICS or valves.

Site 709
System type: ICS system
Installed: 1997
Inspected: 2003
No operational problems.
Usual insulation and insulation UV protective coating degradation.

Site 784
System type: ICS system
Installed: 1996
Inspected: 2003
System was in good condition. Still operating.

Site 790
System type: ICS system
Installed: 1996
Inspected: 2003
This is a sad situation. The owner's wife thought the system was working. Only after I noticed that the system was isolated and opened the isolation valves, did it become obvious that there was a problem. A leak at a pipe joint in the feed line at the roof was seen. There was no insulation on any of the piping on the roof. The owner then recalled that the cold feed piping joint on the roof developed a leak very soon after the system was installed. The owner contacted the installer who came back and supposedly fixed the leak. The owner stated that the unit started leaking again at the same location soon after this repair. The leak is a simple solder joint leak that could be fixed in minutes. Thus, ever since the system was installed, the system has been isolated because of this leak. It appears that the owner isolated the system and has not taken advantage of it since.
She suspects that her husband isolated the system after the installer failed to correct the problem.

DADE COUNTY

Site 22
System type: Pumped - differential controller
Installed: 1996

Inspected: 2003
System is not operating.
Solar system removed (control, pump, etc.)
New tank installed several months ago. Installer did not reconnect the solar system.
Controller and pump missing. Interestingly, the tank installer reconnected the collector loop piping from the tank drain area.
Does not include valves, etc.
Collector is in good shape. Air vent had lot of sediment buildup.
Has collector feed and return lines at top of unit. Will not drain. Installer added a drain valve to compensate for this. Note location of freeze valve.

Site 23
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System is not working.
Leak in collector at header/riser connection. Two locations.
Controller and pump appear fine. Controller tested ok.
Air vent exhibits large amount of sediment calcification.

Site 24
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
Water accumulation at base of water heater. Was from washing machine leak. Told client to correct or water heater will be damaged as well.

Raised elements to 130-135 from 120 after client stated that water was not hot enough (106 F at tap).
Roof sealing material in pitch pans is drying and starting to crack and create gaps for rain penetration.
Exposed piping at flashing locations.
Air vent outlet clogged.

Site 25
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System no longer there.
Client stated that tank had developed a bad leak at top fitting 5 months ago. Owner called solar company that wanted $75 to come out. "Too much money."
Client then called plumber and had tank replaced. Plumber cut lines to solar. Controller and pump missing. Tank not reconnected to solar loop. Client did not know how much tank replacement cost. Asked client why the solar installer was not called since the plumber would charge as much for service call. No explanation. A wasted "free" solar system!

Site 26
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
System not working.
Lack of timer and check valve problem.
Timer has been removed and system pump is plugged directly into the receptacle. Pump is on continuously.
Check valve (in return line) is blocked and therefore, flow is stopped at check valve.
Temperature measurements. Feed: 91.5, Return below check valve: 90 F. Return above check valve 199+ F. Opened return line drain valve and steam (and water) came out. (VOM temperature measurement limit is 199 F. Temperature is easily over that.)
New occupant. 2 years ago. House was in total disarray from tenants that moved in after original system owner. Told them how to fix system - with new timer and check valve, system should be fine. Relative is a plumber.

Site 28
System type: Pumped - differential controller
Installed: 1996
Inspected: 2003
System is working.
Leak calcification at horizontal check valve.
Collector mount bolt coming out of roof surface. Note cracking of roof sealant material.
Metal parts on freeze valve rusting. Insulation degrading.

Site 29
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System not operating.
Control and valve problem.
Client stated that she thought system was still working. Inspection revealed that this was not the case.
Feed line was isolated.
Motorized check valve is not working.
Conducted check of controller with tester. Failed test. Sensor readings were reasonable.
Controller exhibits cackling noise when put in off position.
Anti scald valve stuck on 4 but still working. Loosened with pliers.
Air vent was leaking.
Isolated and drained the system.

Site 30
System type: Pumped - timer control
Installed: 1996
Inspected: 2003

Residence is unoccupied. Was able to inspect exterior. Conducted roof inspection.
Installer used triangular pitch pans.
Pressure relief valve rusting and leaking.
Air vent has sediment covering outlet port.
Pitch pan sealant has gaps for water penetration.
Insulation is deteriorating.

Site 31
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
Operation uncertain.
Client unable to get into house at the time of inspection. States that pump runs all the time. Instructed client on how to check timer type system.

Site 32
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System working fine.
Controller tester indicated controller was ok. Sensor readings reasonable.
Anti scald valve stuck at 4. Loosened with pliers.
Roof sealing material in pitch pans is drying and starting to crack as well as create gaps for rain penetration.
Client states "water is good and plenty and hot."

Site 33
System type: Pumped - differential control
Installed: 1996
Inspected: 2003
System not working.
No power to outlet at which the controller was connected.
Used extension cord to test controller from another receptacle that had power. Very loud (clang) pump when turned on. Pump defective.
Controller and sensors tested fine.
Client stated that water was not hot enough. Raised tank element to 130 F - top and bottom.
Anti valve stuck at 3.

Site 34
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
New occupants. Did not know anything about the solar system.
Collector removed from roof. Mounting brackets still attached to roof.

Tank was removed from room in which it had been installed. Previous solar system piping, components, etc. were gone.

Site 64
System type: Pumped - photovoltaic control
Installed: 1996
Inspected: 2003
System working.
Pump off - intermittent sun and clouds. Came on when sun appeared.
Extreme sediment buildup at air vent exhaust.
Exterior piping has gaps that are not insulated.
Wiring is exposed to exterior conditions. Appears to be weather worn.
Pressure valve handle starting to rust.
Roof sealing material in pitch pans is drying and starting to crack and create gaps for rain penetration.
Metal composite roof is rusting at edges. Soft spots on roof.

Site 68
System type: Pumped – differential controlled
Installed: 1996
Inspected: 2003|
No longer operating. System disconnected.
New roof installed.
Collector taken off and not reinstalled. Lying atop utility shed that houses tank and controls. Client can to afford to reinstall collector and reactivate system. Collector loop sealed off at tank.
Controller was still plugged in. Controller tester indicated that controller functions checked out.

Site 75
System type: Pumped – differential controlled
Installed: 1997
Inspected: 2003|
System is still operating.
Client had anti-scald valve removed after it "failed" in cold mode.
Roof sealant material is starting to separate from pitch pans. Informed client that he should get some sealant material from hardware store and reseal. Knows how to do it.
Exterior pipe insulation protective coating is still relatively intact. Minimal degradation.
Instructed client to add latex paint coating.
Rust residue on roof next to pitch pan and below freeze valve.

Site 81
System type: Pumped – timer controlled
Installed: 1996
Inspected: 2003
System no longer working.

Timer display was invalid. Removed old battery and tried to reset timer to no avail. Could not program. Defective timer.
Pump not working when plugged directly into receptacle.
Pitch pan roof sealant material separated from pitch pan. Holes for moisture access.
Pipe insulation coating had degraded exposing piping. Insulation had pulled away from pipe at pitch pans exposing copper piping. (Or was never completely abutted.)
Pressure relief and freeze valve metals parts rusted.
Air vent port clogged with hard sediment.

Site 91
System type: Pumped -photovoltaic control
Installed: 1996
Inspected: 2003
System is working.
Pipe penetrations were resealed with roofing material. Watermark on ceiling above feed line. (Client noted water running down feed piping. Put towel at floor level to absorb drip. Has been ok since additional sealing took place.) Note that water could have penetrated from air vent valve area (between insulation and piping) and run down between pipe and pipe insulation to utility room ceiling.

Site 95
System type: Pumped – timer controlled
Installed: 1996
Inspected: 2003
No one home. System is still installed. Used foil face material for exterior pipe insulation. Still intact.

Site 103
System type: Pumped – timer controlled
Installed: 1997
Inspected: 2003
No one home. Collector still on roof. Insulation is degraded and missing in sections.

Site 118
System type: Pumped – differential controlled
Installed: 1997
Inspected: 2003
System is working.
Anti-scald valve stuck.
Metal parts of valves on roof are rusting.
Air vent port is clogged with sediment build up.
Feed/return line pitch pan sealant had cracks and openings for moisture penetration.
Sloppy sealing at roof penetrations.

Site 125

System type: Pumped - differential controller
Installed: 1996
Inspected: 2003
System not working as originally designed.
Controller does not come on even when turned to manual on. When controller is plugged in and on auto, power and freeze indicator lights are on. Failed controller tester check. Pump is hard wired to the controller.
Client modified pump wiring so he could plug the pump into a timer that is currently used to power the pump. Client understands system operation and could tell that there was a control problem. Client states that he manually activates the system.
Circa 1980s solar tank is still functional. (Client had another solar system before the SWAP system. Old system's collector was destroyed during Hurricane Andrew.)
Roof inspection revealed that there was a leak in collector. Tube/header location.
Air vent was leaking.
Instructed the client on what he needs to do to correct above deficiencies. Client very interested in renewables.

Site 131
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
System not working.
Check valve appears to be clogged and restricting flow. Timer was not operating. Needs to be reset.
Pressure relief valve on roof did not reseat after being opened to test pressure. Was able to reseat after working on it. Needs to be replaced.
Instructed client to change check valve and to obtain simple timer. Client appears to be capable of doing this himself.

Site 145
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
No one home.
Air vent leaking. Pressure and freeze valves look fine. Left card and note to contact.

Site 154
System type: Pumped - timer control
Installed: 1997
Inspected: 2003
No one home.
Air vent exhibits sediment buildup. Freeze valve and freeze valve plumbing leg placed under backside shade of collector. Left card and note to contact.

Site 164
System type: Pumped - differential controller

Installed: 1996
Inspected: 2003
System was working.
Differential controlled checked out fine. Used controller tester. Freeze control suspect.
High limit set knob was offset. Started at 220 instead of 0. Insect residue in controller.
Sensor readings reasonable.
Very low hot water pressure when two faucets were open. 3/4" out of water heater and reduced to 1/2" before going into wall.

Site 170
System type: Pumped – timer controlled
Installed: 1996
Inspected: 2003
System no longer working.
Timer defective. Pump is still working.
Very difficult to access receptacle where timer is located in shed.
No pitch pan or flashing used at roof penetrations.
Foil material used to protect exterior pipe insulation is still intact.

Site 195
System type: Pumped – differential controlled
Installed: 1997
Inspected: 2003
System is operational.
Controller tester indicates all modes are working. Sensor readings are reasonable.
Anti-scald valve stuck but operating.
Leak at collector pressure relief valve. Freeze valve metal parts rusting.
Gaps in insulation exposing copper piping.
Standard pitch pans do not appear to have been used at roof.
Insulation facing in collector is coming off.

Site 220
System type: Pumped - differential controller
Installed: 1996
Inspected: 2003
System is still operating but collector shaded by tree in south orientation during the main solar gain period. Tree had been trimmed in 1996 but has grown back. Client will cut as advised.
Anti-scald valve is stuck but still operating.
Indoor valve handles are starting to rust and will degrade to a point where they can not be used.
Exposed collector feed and return piping at roof flashing.
Roof pipe insulation coating is still intact. Some cracks due to weatherization.

Site 233
System type: Pumped - photovoltaic control

Installed: 1996
Inspected: 2003
System operating fine. No problems.

Site 247
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
System not working. Timer problem.
Appears to have not been inoperative for some time. Timer is defective.
Pump works when plugged into receptacle. Very noisy. Sound reduced somewhat after pump had been operating for several minutes.
With pump operating: F: 105 F R: 113 F, intermittent sun and clouds.
Drained water from return line. A very large amount of coquina residue was in the water.

Site 249
System type: Pumped - timer control
Installed: 1996
Inspected: 2003
System not working. System removed.
Collector has been removed. Mounting brackets still attached to roof.
New resident. Moved in one year ago. Did not know anything about the solar system.

Site 258
System type: Pumped - photovoltaic control
Installed:1996
Inspected: 2003
No one ever home. Left card and note to contact.

Site 265
System type: Pumped - photovoltaic control
Installed: 1996
Inspected: 2003
System operating.
Pressure relief valve at collector had leaked in the past after opening. Client had successfully closed it. Was not leaking during the inspection. Left the client a new pressure relief valve with instructions on how to replace. Is familiar with plumbing trade.
Air vent is blocked with sediment.
Roof sealing material in pitch pans is drying and starting to crack. This creates gaps for rain penetration.

Site 269
System type: Pumped – differential controlled
Installed: 1997
Inspected: 2003
System still operating.

Anti-scald valve struck but still working.
Escutcheons used at ceiling penetration.
Exterior pipe insulation has degraded and exposed copper piping.

Site 288
System type: Pumped - photovoltaic control
Installed: 1996
Inspected: 2003
System is working.
Air vent had developed a leak at the port and client screwed cap on tight to keep it from leaking. Left new air vent with client and instructions on how to replace.
Freeze valve has mud dauber plugs.
Roof sealing material in pitch pans is drying and starting to crack and create gaps for rain penetration.

Site 292
System type: Pumped - photovoltaic control
Installed: 1996
Inspected: 2003
System is not working.
Pump does not appear to be working. No vibration or sound of any type - during full sun period. Checked wire clips. Somewhat loose but still sufficient contact. PV module is fine. PV wire voltage test acceptable.

Checked feed and return pipe temperatures. No pump activity even in full sun.
Pressure relief valve on roof is leaking. Constant drip. Tried closing to no avail. Water pooling at roof location.
Air vent has scale buildup from previous activity. Not leaking. Roofing material in pitch pans is drying and creating cracks and pools. Isolated the system.

Site 300
System type: Pumped - photovoltaic control
Installed: Ju196
Inspected: Jul 03 No one home. No one ever home. Left card and note to contact.

Site 319
System type: Pumped - photovoltaic control
Installed: 1997
Inspected: 2003
System is working. Anti scald valve stuck at 3. Still functioning.

Site 723
System type: Pumped – differential controlled
Installed: 1997
Inspected: 2003
System still operating.

Control tester indicated all modes operational. Sensor readings reasonable.
Exterior insulation degraded - exposing copper piping

NORTH FLORIDA

It should be noted that system inspections were conducted in Central and South Florida and not North Florida. Systems installed in Central and South Florida included each type of system that was installed throughout Florida - active direct systems using flat plate solar collectors and various control strategies, as well as integral collector storage systems (ICS). Only ICS systems were installed in the North Florida areas. Therefore, it was more feasible to inspect systems installed in Central and South Florida.

Nevertheless, telephone contact was made, whenever possible, with many of the clients in North Florida to determine the status of their systems. (It must be noted that resident telephone numbers have changed, been disconnected, etc., thus making it very difficult to make contact with the residents. In addition, a large majority of clients in North Florida do not have standard street addresses but instead box or route numbers, making locating these remote sites very difficult and time prohibitive. In any event, enough ICS were inspected in Central and South Florida to provide valuable information on these particular systems.) Of the twelve residents contacted in the Suwannee County area, only one was found to have had a problem with their solar system. Contact with the installer that did most of the work in Suwannee County revealed that he had serviced one system. This seems to confirm these telephone results. This same installer revealed that he had serviced a total of five systems that had developed problems in the Tri County area of North Florida. This was out of a total of forty-eight systems installed in that area. These are some of the systems that were repaired as part of the manufacturer's warranty or, during the limited warranty period, with local agency emergency repair funds. The inspector had also made telephone contact with those in the Tri County area that still had their same telephone number and basically confirmed the installer's information.

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APPENDIX C. Printed Copy of Database

ASU Survey – Hi Level Summary

Summary of Estimates

ASU survey, March 1988

24 participants in study

Survey Results Representing All System Types

Component areas	First Failure (average yrs)	Lifetime (average yrs)	Reliability Index (average)
Collector	10.9	20.2	8.6
Controller	7.5	13.0	8.5
Sensors	5.5	11.0	7.5
Tanks	6.6	10.5	7.6
Pumps	6.0	9.0	7.5
Heat Transfer	4.0	6.0	6.0
Piping	8.5	11.3	6.5
Valves	4.7	6.9	6.2
Averages	6.7	11.0	7.3

Experience of Participants in Years

ICS	6
Drainback	14
Indirect Thermosiphon	0
Pool	2
Not Specified	7
Total	29

ASU Survey – Detailed

Summary of Estimates

ASU survey, March 1988
24 participants in study

	Survey Results Representing All System Types		
	First Failure (ave yrs)	**Lifetime (ave yrs)**	**Reliability Index (ave)**
Collector	**10.9**	**20.2**	**8.6**
Passage blocked	11.0	19.0	9.0
Copper collector painted	10.0	18.5	8.5
Copper collector selective surface	10.5	21.0	9.0
Aluminum collector painted	7.5	17.0	7.5
Aluminum collector selective surface	6.5	17.0	8.0
Fluid passages	9.0	19.0	8.5
Collector cover	16.0	30.0	9.5
Collector enclosure	15.0	25.0	9.0
Collector gaskets	13.0	15.0	8.5
Controller	**7.5**	**13.0**	**8.5**
Sensors	**5.5**	**11.0**	**7.5**
Tanks	**6.6**	**10.5**	**7.6**
Solar storage tank glass	7.5	11.0	7.5
Solar storage tank steel	7.0	11.0	6.5
Solar storage tank thermostat	6.0	11.0	8.5
Expansion tank	6.0	9.0	8.0
Pumps	**6.0**	**9.0**	**7.5**
Horizontal shaft pumps	6.5	10.0	8.0
Vertical shart pumps	5.5	8.0	7.0
Heat Transfer	**4.0**	**6.0**	**6.0**
Glycol fluid	4.0	6.0	6.0
Piping	**8.5**	**11.3**	**6.5**
Piping insulation painted	8.0	8.0	9.0
Piping insulation w/AL tape	9.0	14.5	4.0
Piping insulation untreated	3.0	6.0	6.0
Valves	**4.7**	**6.9**	**6.2**
Valve, air vent	4.0	6.5	6.0
Valve, Draindown	3.5	6.0	5.5
Valve, spring check valve	5.0	7.5	6.5
Valve, flapper check valve	5.0	7.0	6.0
Valve, drain ball valve	7.0	8.5	8.0
Valve, vent	4.5	6.5	6.0
Valve, mix or tempering	3.5	5.5	4.5
Valve, P&T	4.5	7.0	6.5
Valve, pressure	5.5	8.0	7.0
Totals	6.7	11.0	7.3

Experience of Participants in Years

ICS	6
Drainback	14
Indirect Thermosiphon	0
Pool	2
Unknown	7
Total	29

FSEC Survey – Hi Level Summary

Summary of Estimates

FSEC survey, March 1988

Five participants in study

Component areas	**Lifetime (average yrs)**
Collector	26.0
Controller	10.1
Sensors	no data
Tanks	9.7
Pumps	10.9
Heat Transfer	9.7
Piping	20.0
Valves	8.2
Averages	13.5

FSEC Survey – Detailed

DHW SYSTEM COMPONENT LIFETIME SURVEY

Survey of Industry conducted by John Harrison, Florida Solar Energy Center (1993)

Respondent: Type of industry activity (5 individual respondents)	Company A Distributor Installer	Company B Manufacturer	Company C Manufacturer Distributor Installer	Company D Installer	Company E Manufacturer Distributor Installer		
SYSTEM COMPONENT	ANTICIPATED LIFETIME - IN YEARS					COMPONENT AVERAGE	AVERAGE BY CATEGORY
Flat Plate Collector	30 (20+)	30.0	30.0	40.0	15.0	29.0	
ICS Collector		30.0	30.0	9 (8-10)		23.0	26.0
Pump DC	12.5 (10-15)	12.5 (10-15)	7.0	9 (3-15)	8.0	9.8	
Pump AC	12.5 (10-15)	10 (8-12)	15.0	12.5 (10-15)	10.0	12.0	10.9
Storage Tank - Solar	12.5 (10-15)	9.5 (7-12)	8.5 (7-10)	7.5 (5-10)	9.0	9.4	
Storage Tank - Conventional	12.5 (10-15)	9.5 (7-12)	8.5 (7-10)	7.5 (5-10)	9.0	9.4	9.4
Controller - Differential	9 (8-10)	7 (4-10)	10.0	6.5 (8-13)	12.0	8.9	
Controller - PV	10.0	20.0	17.5 (15-20)	10+		14.4	
Controller - Timer	10.0	10.0	10.0		8.0	9.5	
Controller - Snap Switch			7.0		8.0	7.5	10.1
Heat Exchanger (Internal)	12.5 (10-15)	10+	8.0	10+		10.1	
Heat Exchanger (External)	15 (10-20)	10.0	10.0	10+	9.0	10.8	
Expansion Tank	7.5 (5-10)	10.0	7.0	7.5 (5-10)	10.0	8.4	9.7
Freeze Prevention Valves	4 (3-5)	3.0	5.0	5.0		4.3	
Air Vent	4 (3-5)	3.5 (3-4)	7.0	5.0	8.0	5.5	
Pressure/Temp Relief Valve	10.0	10 (1-10)	8.0	10.0	7.0	9.0	
Pressure Relief Valve	10.0	10 (1-10)	20.0	10.0	8.0	11.6	
Vacuum Breaker	4 (3-5)	6.5 (5-8)	5.0	5.0	15.0	7.1	
Isolation Valve - Gate		9 (8-10)	0.5	3 (2-4)	10.0	5.6	
Isolation Valve - Ball	15 (10-20)	12.5 (10-15)	10.0	12.5 (10-15)	15.0	13.0	
Drain Valve	10.0	20.0	20.0	8.5 (7-10)	15.0	14.7	
Check Valve - Vertical	6 (5-7)	6.5 (3-10)	2.0	5.0	10.0	5.9	
Check Valve - Horizontal	6 (5-7)	6.5 (3-10)	1.0	2.0	10.0	5.1	
Check Valve - Motorized	10+		10.0	6 (5-7)		8.6	8.2
Piping - Copper	20+	20+	20.0	20+	20+	20.0	20.0

NREL Survey – Hi Level Summary

Summary of Estimates

NREL Survey of Installers

Component Mean Lifetime Estimates--Overall Averages

Component areas	Average years
Collector	22.5
Controller	20.0
Sensors	15.0
Tanks	18.5
Pumps	9.5
Heat Transfer	3.0
Piping	7.0
Valves	8.6
Averages	

NREL Survey – Detailed

NREL Survey of Sacramento Contractors 1994
Data as presented in draft NREL report

Component Mean Lifetime[1] Estimates

Component	Best Conditions (i.e., properly installed & maintained)			Worst Conditions (i.e., poor water qual, over temp)			
Component	**Low[2]**	**High[3]**	**Average**	**Low[2]**	**High[3]**	**Average**	**Overall Average**
Collector							
Glass cover	30	60	45	30	60	45	45
Polycarbonate cover	5	20	12.5	5	20	12.5	12.5
Plastic films (Tedlar)	5	20	12.5	5	20	12.5	12.5
Copper absorber	20	60	40	10	30	20	30
EPDM absorber	5	20	12.5	5	20	12.5	12.5
Glycol fluid (heat transfer)	5	10	7.5	3	6	4.5	6
Tanks							
Glass-lined	8	25	16.5	5	20	12.5	14.5
Polypropylene (unpress.)	20	40	30	10	20	15	22.5
Pumps	5	20	12.5	3	10	6.5	9.5
Controller							
Current models	10	30	20	10	30	20	20
Sensors	10	20	15	10	20	15	15
Loop regulation (valves)							
Mixing valve, no trap	3	7	5	2	5	3.5	4.25
Mixing valve, trapped	5	30	17.5	5	10	7.5	12.5
Check valves	10	40	25	5	10	7.5	16.25
Vent valve	3	8	5.5	2	6	4	4.75
Vacuum relief	3	10	6.5	2	6	4	5.25
Draindown valve	3	9	6	2	6	4	5
Expansion tank	5	20	12.5	2	6	4	8.25
Pressure relief valve	10	25	17.5	4	12	8	12.75
Pipe insulation							
painted	2	8	5	2	8	5	5
aluminum tape	8	10	9	8	10	9	9

Notes:
1) Mean lifetime: Defined as the time for 50% of the population of operating units to fail.
2) Low: lowest estimate provided by contractors.
3) High: highest estimate provided by contractors.

Combo – Hi Level Summary

Combined SWAP/HECO/Sacramento High Level Summary of Problems

	SYSTEM TYPE						
	ICS	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Problem areas			**TOTAL REPORTED PROBLEMS**				
Collector problems	27	56	6	1	82	71	243
Controller problems	0	55	0	1	17	26	99
Sensor Problems	0	112	1	1	26	77	217
Tank Problems	0	76	11	0	0	74	161
Pump Problems	0	79	0	2	6	68	155
Heat Transfer Problems	0	48	3	0	1	14	66
Piping problems	1	39	2	0	1	21	64
Valve Problems	7	200	28	3	40	161	439
Totals	**35**	**665**	**51**	**8**	**173**	**512**	1444
Problem areas			**PROBLEMS AS A PERCENTAGE OF TOTAL**				
Collector problems	77.1%	8.4%	11.8%	12.5%	47.4%	13.9%	16.8%
Controller problems	0.0%	8.3%	0.0%	12.5%	9.8%	5.1%	6.9%
Sensor Problems	0.0%	16.8%	2.0%	12.5%	15.0%	15.0%	15.0%
Tank Problems	0.0%	11.4%	21.6%	0.0%	0.0%	14.5%	11.1%
Pump Problems	0.0%	11.9%	0.0%	25.0%	3.5%	13.3%	10.7%
Heat Transfer Problems	0.0%	7.2%	5.9%	0.0%	0.6%	2.7%	4.6%
Piping problems	2.9%	5.9%	3.9%	0.0%	0.6%	4.1%	4.4%
Valve Problems	20.0%	30.1%	54.9%	37.5%	23.1%	31.4%	30.4%
Totals	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

SWAP – Hi Level Summary

SWAP High Level Summary of Problems

Installations, 1993-1997;			SYSTEM TYPE				
Inspections in 2003	**ICS**	**Pumped[1]**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Total Installed systems	393	406	2	no data	0	0	801
Total attempted inspections	80	81		8			169
Total actual inspections	76	67		8			151
Total operational systems	62	32		6			100
Total non-operational systems	14	35		2			51
Percent of operational systems	81.6%	47.8%		75.0%			66.2%
Sample proportion of problems relative to total inspected	18.4%	52.2%		25.0%			
Lower 95% confidence limits on proportion	8.0%	37.0%		8.0%			
Upper 95% confidence limits on proportion	24.0%	65.0%		48.0%			
Problem areas	**TOTAL REPORTED PROBLEMS FOR ALL INSPECTIONS**						
Collector problems	14	16		0			30
Controller problems	0	11		0			11
Sensor Problems	0	1		0			1
Tank Problems	0	2		0			2
Pump Problems	0	4		1			5
Heat Transfer Problems	0	0		0			0
Piping problems	1	5		0			6
Valve Problems	6	32		2			40
Totals	**21**	**71**		**3**			**95**
Problems per inpected system	3.6	0.9		2.7			1.6
Problem areas	**PROBLEMS AS A PERCENTAGE OF TOTAL**						
Collector problems	66.7%	22.5%		0.0%			31.6%
Controller problems	0.0%	15.5%		0.0%			11.6%
Sensor Problems	0.0%	1.4%		0.0%			1.1%
Tank Problems	0.0%	2.8%		0.0%			2.1%
Pump Problems	0.0%	5.6%		33.3%			5.3%
Heat Transfer Problems	0.0%	0.0%		0.0%			0.0%
Piping problems	4.8%	7.0%		0.0%			6.3%
Valve Problems	28.6%	45.1%		66.7%			42.1%
Totals	100.0%	100.0%		100.0%			100.0%

			Total Installed Systems				
	ICS	**Pumped[1]**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
NUMBER OF SYSTEMS INSTALLED	**393**	**406**	**2**				**801**

Notes:

1. An undetermined number of these were PV control systems.

SWAP		
Upper 95% confidence limit	24.0%	65.0%
Lower 95% confidence limits	8.0%	37.0%
Proporation of problems as % installed	18.4%	52.2%

SWAP – Mid Level Summary

Summary of Problems			SYSTEM TYPE				
SWAP Installs, 1993-1997; 200 inspects	**ICS**	**Direct circ**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
SYSTEMS INSTALLED	**393**	**406**	**2**				
INSPECTED SYSTEMS W/PROBLEMS	**73**	**68**	**0**	**8**	**0**	**0**	**149**
Collector problems	**14**	**16**	**0**	**0**	**0**	**0**	**30**
Faulty Collector Problem Totals	9	16	0	0	0	0	25
Collector Mounting Problem Totals	5	0	0	0	0	0	5
Controller problems	**0**	**11**	**0**	**0**	**0**	**0**	**11**
Diff Controller problem Totals	0	7	0	0	0	0	7
PV Controller problem Totals	0	0	0	0	0	0	0
Timer Controller problem Totals	0	4	0	0	0	0	4
Sensor Problems	**0**	**1**	**0**	**0**	**0**	**0**	**1**
Sensor failure Totals	0	1	0	0	0	0	1
Sensor wiring problem Totals	0	0	0	0	0	0	0
Tank Problems	**0**	**2**	**0**	**0**	**0**	**0**	**2**
Solar Storage Water Heater problem Totals	0	2	0	0	0	0	2
Electric Auxiliary Water Heater problem	0	0	0	0	0	0	0
Gas Auxiliary Water Heater problem totals	0	0	0	0	0	0	0
Drainback tank problem totals	0	0	0	0	0	0	0
Pump Problems	**0**	**4**	**0**	**1**	**0**	**0**	**5**
Pumps problem totals	0	4	0	1	0	0	5
Heat Transfer Problems	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Heat exchanger problem Totals	0	0	0	0	0	0	0
Heat transfer fluid problem Totals	0	0	0	0	0	0	0
Piping problems	**1**	**5**	**0**	**0**	**0**	**0**	**6**
Piping problems Totals	1	5	0	0	0	0	6
Insulation exterior problem Totals	0	0	0	0	0	0	0
Valve Problems	**6**	**32**	**0**	**2**	**0**	**0**	**40**
Valve, air vent problem totals	0	14	0	1	0	0	15
Valve, automatic draindown Totals	0	0	0	0	0	0	0
Valve, anti-scald problem Totals	0	8	0	0	0	0	8
Valve, check problem Totals	0	2	0	0	0	0	2
Valve, fill drain problem Totals	0	0	0	0	0	0	0
Valve, freeze Totals	6	5	0	0	0	0	11
Valve, isolation and supply Totals	0	0	0	0	0	0	0
Valve, mixing/temp problem Totals	0	1	0	0	0	0	1
Valve T&P collector loop problem Totals	0	2	0	1	0	0	3
Valve, Vacuum breaker problem Totals	0	0	0	0	0	0	0
Totals	**21**	**71**	**0**	**3**	**0**	**0**	**95**

SWAP – Detailed Summary

Detailed Summary of Problems	System Type						
SWAP, 1993-1997; 200 Inspections 2003-2004	ICS	Pumped	Thermo	PV control	Pool	Unknown	Totals
SYSTEMS INSTALLED	**393**	**406**	**2**				
INSPECTED SYSTEMS W/PROBLEMS	**73**	**68**		**8**			**149**
Collector Problem Totals	**9**	**16**	**0**	**0**	**0**	**0**	**25**
-defective collector							0
-leaking	8	5					13
-leaking (source unknown)							0
-header tubes leaking							0
-header tube leaking		3					3
-riser to header connection leaking							0
-riser tubes leaking							0
-leaking due to freeze damage		1					1
-glazing is broken							0
-O-rings defective							0
-plug on pool panel defective							0
-panels blew off roof							0
-enclosure structural problem							0
-no fluid flow in collector							0
-glazing extremely dirty							0
-structural damage to roof from collector leak							0
-collector bypassed							0
-collector removed for re roofing							0
-collector removed permanently	1	6					7
-unknown problem		1					1
Collector Mounting Problem Totals	**5**	**0**	**0**	**0**	**0**	**0**	**5**
-collector not firmly attached to roof							0
-defective mounting	1						1
-mounting bolts not secured							0
-improper structural mounting method	1						1
-improper roof flashing used							0
-flashing not sealed							0
-roof penetration not sealed	1						1
-leak at mounting points	1						1
-collector not tilted for drainage							0
-improper orientation (azimuth)	1						1
-unknown problem							0
Diff Controller problem Totals	**0**	**7**	**0**	**0**	**0**	**0**	**7**
-defective controller		6					6
-switch on "on" position							0
-high temp limit setting inaccurate							0
-loose connections at sensor terminal							0
-improperly programmed							0
-controller stays on all the time							0
-controller operates only in manual mode							0
-system shuts off at wrong high limit or runs continus							0
-no power to the controller		1					1
-unknown problem							0

Detailed Summary of Problems	System Type						
SWAP, 1993-1997; 200 Inspections 2003-2004	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
PV Controller problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-pv module shaded							0
-pv module too small for head							0
Timer Controller problem Totals	**0**	**4**	**0**	**0**	**0**	**0**	**4**
-defective timer		4					4
-wrong on/off time							0
-current time incorrect							0
-unplugged from power source							0
Sensor failure Totals	**0**	**1**	**0**	**0**	**0**	**0**	**1**
-defective sensor							0
-defective collector sensor							0
-defective tank sensor							0
-collector sensor not properly attached/secured							0
-tank sensor not properly attached/secured							0
-improper connection method							0
-improper mounting location (collector)							0
-sensor not protected from environment		1					1
-sensor not installed (required)							0
-sensor and controller not compatible							0
-defective snap switch							0
-unknown problem							0
-defective temp gauge							0
-leaking at body of gauge							0
-defective transformer							0
Sensor wiring problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective sensor wiring							0
-defective wire connections							0
-open collector sensor wiring							0
-shorted collector sensor wiring							0
-open water heater sensor wiring							0
-shorted water heater sensor wiring							0
-sensor wires reversed							0
-sensor wire run not secured							0
-sensor wires not connected							0
-sensor wires crimped							0
-sensor wires chaffed from obstructions							0
-wiring insulation chewed off by rodents							0
-line cord problem							0
-roof wiring penetrations not sealed properly							0
-unknown problem							0
Solar Storage Water Heater problem Totals	**0**	**2**	**0**	**0**	**0**	**0**	**2**
-defective water heater		1					1
-tank fitting leak							0
-internal tank leak							0
-thermosiphon tank leak							0
-defective element							0
-defective thermostat							0
-defective thermostat wiring							0
-thermostat set too low		1					1
-thermostat tripped (overheating)							0
-voltage to water heater inadequate							0
-defective circuit breaker							0
-thermosiphon tank shell coming apart							0
-tank outer shell cracked							0
-white deposits in storage tank							0
-solar blocked from tank bottom calcification							0
-unknown problem							0

Detailed Summary of Problems				**System Type**			
SWAP, 1993-1997; 200 Inspections 2003-2004	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Electric Auxiliary Water Heater problem	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective tank							0
-internal tank leak							0
-defective element							0
-leak at element bolt							0
-defective thermostat							0
-thermostat tripped							0
-upper thermostat set too low							0
-lower thermostat set too low							0
-no electrical power to tank							0
-old water heater in efficient without solar							0
-not properly insulated							0
-unknown problem							0
Gas Auxiliary Water Heater problem totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective tank							0
-internal tank leak							0
-defective thermocouple							0
-loose thermocouple connection							0
-failure to ignite							0
-pilot light off							0
-pilot valve defective							0
-unknown problem							0
Drainback tank problem totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective tank							0
-tank leaks							0
-level indicator leaks							0
-tank is empty of fluid							0
-tank water level low							0
-improper fluid level							0
-tank overfilled							0
-unknown problem							0
-expansion tank problem							0
Pumps problem totals	**0**	**4**	**0**	**1**	**0**	**0**	**5**
-pump failure		3		1			4
-defective pump							0
-defective rotor							0
-defective gasket							0
-motor failure							0
-defective capacitor							0
-replaced cartridge							0
-bearing dry (need lubrication)							0
-leak in pump		1					1
-leak at pump connections							0
-loose pump mounting flanges							0
-air trapped in pump							0
-improperly installed							0
-required pump not installed							0
-unknown problem							0
-stuck shaft, impeller, or coupling							0
-pressure problem							0
-no pressure							0
-no collector loop pressure							0
-pressure too high, pool sweep runs with solar on							0

Detailed Summary of Problems	System Type						
SWAP, 1993-1997; 200 Inspections 2003-2004	ICS	Pumped	Thermo	PV control	Pool	Unknown	Totals
Heat exchanger problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-heat exchanger leak							0
-inefficient due to clogging							0
-isolated from system							0
-defective heat exchanger							0
-air in heat exchanger							0
-unknown problem							0
Heat transfer fluid problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-insufficient glycol mixture							0
-loss of chemical stability							0
-loss of fluid due to a leak							0
-fluid level low							0
-no fluid in system							0
-low pressure in loop							0
-no pressure in heat transfer loop							0
-recharge of fluid required							0
-wrong type of glycol used							0
Piping problems Totals	**1**	**5**	**0**	**0**	**0**	**0**	**6**
-entrapped air							0
-leak in piping		1					1
-leak at roof piping penetration	1	4					5
Insulation exterior problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective insulation							0
-insulation deteriorating (non UV)							0
-uv protective foil tape deteriorating							0
-new insulation needed							0
-animals destroying insulation							0
-wrong type (foam/plastic) insulation used							0
-not used (required)							0
Valve, air vent problem totals	**0**	**14**	**0**	**1**	**0**	**0**	**15**
-defective air vent		14		1			15
-internal leak							0
-air in hot water line							0
-needs air vent							0
-leak at plumbing fitting							0
-not operating (air in system)							0
-not installed (required)							0
-inoperative due to freeze							0
-unknown problem							0
Valve, automatic draindown Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-valve defective							0
-does not open or close fully							0
-valve stuck in drain position							0
-valve stuck in fill position							0
-o-rings defective							0
-noisy operation							0
-unknown problem							0
Valve, anti-scald problem Totals	**0**	**8**	**0**	**0**	**0**	**0**	**8**
-defective valve		8					8
-needs internal rebuilding							0
-unknown problem							0

Detailed Summary of Problems	System Type						
SWAP, 1993-1997; 200 Inspections 2003-2004	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Valve, check problem Totals	**0**	**2**	**0**	**0**	**0**	**0**	**2**
-defective valve		2					2
-leaking							0
-valve stuck open - internal leak							0
-not installed (required)							0
-unknown problem							0
Valve, fill drain problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-valve defective							0
-internal leak at seals							0
-packing nuts loose							0
-not installed (required)							0
-unknown problem							0
Valve, freeze Totals	**6**	**5**	**0**	**0**	**0**	**0**	**11**
-valve defective	1	5					6
-valve leaking	5						5
-freeze plug problem							0
-unknown problem							0
Valve, isolation and supply Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective valve							0
-leak at seats							0
-improper setting (position)							0
-not installed (required)							0
-defective motorized pool valve							0
-isolation valve not sealing completely							0
-unknown problem							0
-internal leak at seal							0
Valve, mixing/temp problem Totals	**0**	**1**	**0**	**0**	**0**	**0**	**1**
-defective valve		1					1
-leaking							0
-needs internal rebuilding							0
-improper temperature setting							0
-loose packing nut							0
-stuck due to deposits							0
-required - due to water being too hot							0
-unknown problem							0
Valve T&P collector loop problem Totals	**0**	**2**	**0**	**1**	**0**	**0**	**3**
-defective collector valve		2		1			3
-leaking collector valve							0
-discharge not routed to proper location							0
-leaking at port - did not reseal after opening							0
-unknown problem							0
-defective water heater valve							0
-internal leak on water heater valve							0
Valve, Vacuum breaker problem Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**
-defective valve							0
-leaking							0
-valve has been plugged							0
-unknown problem							0
Summary	**21**	**71**	**0**	**3**	**0**	**0**	**95**
Checksum							**95**

HECO Presentation

HECO Summary Information

Presented by Ron Richmond at *Solar Power* Meeting 2005, Washington DC

Preliminary Research Estimates 1995

	Estimated Life (yrs)	Warranty (yrs)	Claims
Collectors	>20	5 & 10	<0.1%
Tanks	>15	5	<1.5%
AC pumps	>10	1 & 1.5	<1.0%
DC pumps	>5	1	<3.0%
Controllers	>10	10	<1.0%

Actual Warranty Claims (1996-2004)

	Equipment installed	Claims	Warranty rate
Collectors	~40,000	63	0.16%
Tanks	~27,000	21	0.08%
Pumps	~27,000	38	0.14%
Controllers	~25,000	36	0.14%

Estimated total installations	27000
Total claims	158
Warranty rate	0.6%

HECO – Hi Level Summary

HECO High Level Summary of Problems							
HECO Oahu records, 1996-1999				SYSTEM TYPE			
	ICS	Direct circ	Thermo	PV control	Pool	Unknown	Totals
Total Installed	unknown	unknown	unknown	unknown	unknown	unknown	unknown
Service Calls		9		2		8	19
Calls as Percentage of total		47.4%		10.5%		42.1%	100.0%
Problem areas				TOTAL REPORTED PROBLEMS			
Collector problems	0	0	0	0	0	0	0
Controller problems	0	8	0	0	0	1	9
Sensor Problems	0	0	0	1	0	1	2
Tank Problems	0	0	0	0	0	0	0
Pump Problems	0	1	0	1	0	0	2
Heat Transfer Problems	0	0	0	0	0	0	0
Piping problems	0	0	0	0	0	0	0
Valve Problems	0	0	0	0	0	6	6
Totals	**0**	**9**	**0**	**2**	**0**	**8**	**19**
Problems per service call		1.0		1.0		1.0	1.0
Problem areas				PROBLEMS AS A PERCENTAGE OF TOTAL			
Collector problems		0.0%		0.0%		0.0%	0.0%
Controller problems		88.9%		0.0%		12.5%	47.4%
Sensor Problems		0.0%		50.0%		12.5%	10.5%
Tank Problems		0.0%		0.0%		0.0%	0.0%
Pump Problems		11.1%		50.0%		0.0%	10.5%
Heat Transfer Problems		0.0%		0.0%		0.0%	0.0%
Piping problems		0.0%		0.0%		0.0%	0.0%
Valve Problems		0.0%		0.0%		75.0%	31.6%
Totals		100.0%		100.0%		100.0%	100.0%

HECO – Mid Level Summary

Summary of Problems			SYSTEM TYPE				
HECO records, 1996-1999	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
TOTAL INSTALLED							
SERVICE CALLS		**9**		**2**		**8**	**19**
Collector problems	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Faulty Collector Problem Totals	0	0	0	0	0	0	0
Collector Mounting Problem Totals	0	0	0	0	0	0	0
Controller problems	**0**	**8**	**0**	**0**	**0**	**1**	**9**
Diff Controller problem Totals	0	7	0	0	0	1	8
PV Controller problem Totals	0	0	0	0	0	0	0
Timer Controller problem Totals	0	1	0	0	0	0	1
Sensor Problems	**0**	**0**	**0**	**1**	**0**	**1**	**2**
Sensor failure Totals	0	0	0	0	0	1	1
Sensor wiring problem Totals	0	0	0	1	0	0	1
Tank Problems	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Solar Storage Water Heater problem Totals	0	0	0	0	0	0	0
Electric Auxiliary Water Heater problem	0	0	0	0	0	0	0
Gas Auxiliary Water Heater problem totals	0	0	0	0	0	0	0
Drainback tank problem totals	0	0	0	0	0	0	0
Pump Problems	**0**	**1**	**0**	**1**	**0**	**0**	**2**
Pumps problem totals	0	1	0	1	0	0	2
Heat Transfer Problems	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Heat exchanger problem Totals	0	0	0	0	0	0	0
Heat transfer fluid problem Totals	0	0	0	0	0	0	0
Piping problems	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Piping problems Totals	0	0	0	0	0	0	0
Insulation exterior problem Totals	0	0	0	0	0	0	0
Valve Problems	**0**	**0**	**0**	**0**	**0**	**6**	**6**
Valve, air vent problem totals	0	0	0	0	0	1	1
Valve, automatic draindown Totals	0	0	0	0	0	0	0
Valve, anti-scald problem Totals	0	0	0	0	0	0	0
Valve, check problem Totals	0	0	0	0	0	1	1
Valve, fill drain problem Totals	0	0	0	0	0	0	0
Valve, freeze Totals	0	0	0	0	0	0	0
Valve, isolation and supply Totals	0	0	0	0	0	0	0
Valve, mixing/temp problem Totals	0	0	0	0	0	0	0
Valve T&P collector loop problem Totals	0	0	0	0	0	4	4
Valve, Vacuum breaker problem Totals	0	0	0	0	0	0	0
Totals	**0**	**9**	**0**	**2**	**0**	**8**	**19**

Sacramento – Hi Level Summary

Detailed Summary of Problems							
Sacramento Data			**System Type**				
		SMUD			**Murray**		
	ICS	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Total Installations	423	1889	907	unknown	unknown	unknown	3219
Percent of total installations	13.1%	58.7%	28.2%				
Service Calls	31	298	61	3	242	495	1130
Proporation of problems as % of total installed	7.3%	15.8%	6.7%				
Lower 95% confidence limits for proportion	5%	14%	5%				
Upper 95% confidence limit for proportion	9%	17%	8%				
Percent of total service calls	2.7%	26.4%	5.4%	0.3%	21.4%	43.8%	100.0%
Problem areas			**TOTAL REPORTED PROBLEMS**				
Collector problems	13	40	6	1	82	71	213
Controller problems	0	36	0	1	17	25	79
Sensor Problems	0	111	1	0	26	76	214
Tank Problems	0	74	11	0	0	74	159
Pump Problems	0	74	0	0	6	68	148
Heat Transfer Problems	0	48	3	0	1	14	66
Piping problems	0	34	2	0	1	21	58
Valve Problems	1	168	28	1	40	155	393
Totals	**14**	**585**	**51**	**3**	**173**	**504**	**1330**
Problems per service call	0.5	2.0	0.8	1.0	0.7	1.0	1.2
Percent of problem per total installed	3.3%	31.0%	5.6%				
Problem areas			**PROBLEMS AS A PERCENTAGE OF TOTAL**				
Collector problems	92.9%	6.8%	11.8%	33.3%	47.4%	14.1%	16.0%
Controller problems	0.0%	6.2%	0.0%	33.3%	9.8%	5.0%	5.9%
Sensor Problems	0.0%	19.0%	2.0%	0.0%	15.0%	15.1%	16.1%
Tank Problems	0.0%	12.6%	21.6%	0.0%	0.0%	14.7%	12.0%
Pump Problems	0.0%	12.6%	0.0%	0.0%	3.5%	13.5%	11.1%
Heat Transfer Problems	0.0%	8.2%	5.9%	0.0%	0.6%	2.8%	5.0%
Piping problems	0.0%	5.8%	3.9%	0.0%	0.6%	4.2%	4.4%
Valve Problems	7.1%	28.7%	54.9%	33.3%	23.1%	30.8%	29.5%
Totals	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes:
1 Includes only ICS, Pumped and Thermosiphon totals

Sacramento – Mid Level Summary

Detailed Summary of Problems							
Sacramento Data	**System Type**						
	SMUD				**Murray**		
	ICS	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
TOTAL INSTALLED	**423**	**1889**	**907**	**unknown**	**unknown**	**unknown**	
SERVICE CALLS	**31**	**298**	**61**	**3**	**242**	**495**	**1130**
Collector problems	**13**	**40**	**6**	**1**	**82**	**71**	**213**
Faulty Collector Problem Totals	11	28	2	1	62	59	163
Collector Mounting Problem Totals	2	12	4	0	20	12	50
Controller problems	**0**	**36**	**0**	**1**	**17**	**25**	**79**
Diff Controller problem Totals	0	29	0	0	16	23	68
PV Controller problem Totals	0	0	0	1	0	1	2
Timer Controller problem Totals	0	7	0	0	1	1	9
Sensor Problems	**0**	**111**	**1**	**0**	**26**	**76**	**214**
Sensor failure Totals	0	82	1	0	19	54	156
Sensor wiring problem Totals	0	29	0	0	7	22	58
Tank Problems	**0**	**74**	**11**	**0**	**0**	**74**	**159**
Solar Storage Water Heater problem Totals	0	30	9	0	0	50	89
Electric Auxiliary Water Heater problem	0	27	1	0	0	7	35
Gas Auxiliary Water Heater problem totals	0	1	1	0	0	14	16
Drainback tank problem totals	0	16	0	0	0	3	19
Pump Problems	**0**	**74**	**0**	**0**	**6**	**68**	**148**
Pumps AC problem totals	0	74	0	0	6	68	148
Heat Transfer Problems	**0**	**48**	**3**	**0**	**1**	**14**	**66**
Heat exchanger problem Totals	0	9	0	0	0	2	11
Heat transfer fluid problem Totals	0	39	3	0	1	12	55
Piping problems	**0**	**34**	**2**	**0**	**1**	**21**	**58**
Piping problems Totals	0	1	0	0	1	2	4
Insulation exterior problem Totals	0	33	2	0	0	19	54
Valve Problems	**1**	**168**	**28**	**1**	**40**	**155**	**393**
Valve, air vent problem totals	0	14	0	0	0	44	58
Valve, automatic draindown Totals	0	72	0	0	0	9	81
Valve, anti-scald problem Totals	0	1	0	0	0	2	3
Valve, check problem Totals	0	8	0	0	7	8	23
Valve, fill drain problem Totals	1	8	0	0	2	4	15
Valve, freeze Totals	0	1	8	1	1	18	29
Valve, isolation and supply Totals	0	6	0	0	30	20	56
Valve, mixing/temp problem Totals	0	46	5	0	0	24	75
Valve T&P collector loop problem Totals	0	7	7	0	0	15	29
Valve, Vacuum breaker problem Totals	0	5	8	0	0	11	24
Totals	**14**	**585**	**51**	**3**	**173**	**504**	**1330**

Sacramento – Detailed Summary

Detailed Summary of Problems							
Sacramento Data				**System Type**			
		SMUD			Murray		
Bergquam and Murray records, 1991-1999, SMUD	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
TOTAL INSTALLED	**423**	**1889**	**907**	**unknown**	**unknown**	**unknown**	**3219**
SERVICE CALLS	**31**	**298**	**61**	**3**	**242**	**495**	**1130**
Collector Problem Totals	**11**	**28**	**2**	**1**	**62**	**59**	**163**
-defective collector	1	3	0		6	2	12
-leaking		1	0		1		2
-leaking (source unknown)	2	6	0	1	24	13	46
-header tubes leaking		0	0		3	3	6
-header tube leaking		0	1				1
-riser to header connection leaking		8	0				8
-riser tubes leaking		0	0		3	2	5
-leaking due to freeze damage	2	3	0		6	20	31
-glazing is broken	5	3	0			3	11
-O-rings defective		0	1		8	1	10
-plug on pool panel defective		0	0		2		2
-panels blew off roof		0	0		1		1
-enclosure structural problem		2	0			1	3
-no fluid flow in collector		2	0				2
-glazing extremely dirty		0	0			2	2
-structural damage to roof from collector leak		0	0			1	1
-collector bypassed		0	0			1	1
-collector removed for re roofing	1	0	0		2	3	6
-collector removed permanently		0	0		1	1	2
-unknown problem		0	0		5	6	11
Collector Mounting Problem Totals	**2**	**12**	**4**	**0**	**20**	**12**	**50**
-collector not firmly attached to roof		1	0		5		6
-defective mounting	1	4	0		10	4	19
-mounting bolts not secured		1	1				2
-improper structural mounting method		2	0		1	1	4
-improper roof flashing used		1	0			1	2
-flashing not sealed	1	1	1			1	4
-roof penetration not sealed		0	0		1	3	4
-leak at mounting points		1	2			1	4
-collector not tilted for drainage		0	0			1	1
-improper orientation (azimuth)		1	0				1
-unknown problem		0	0		3		3
Diff Controller problem Totals	**0**	**29**	**0**	**0**	**16**	**23**	**68**
-defective controller		23	0		10	16	49
-switch on "on" position		1	0				1
-high temp limit setting inaccurate		0	0			1	1
-loose connections at sensor terminal		0	0			1	1
-improperly programmed		0	0		2		2
-controller stays on all the time		0	0			1	1
-controller operates only in manual mode		1	0			2	3
-system shuts off at wrong high limit or runs continus		1	0			1	2
-no power to the controller		2	0				2
-unknown problem		1	0		4	1	6
PV Controller problem Totals	**0**	**0**	**0**	**1**	**0**	**1**	**2**
-pv module shaded		0	0	1			1
-pv module too small for head		0	0			1	1

Sacramento Data			**System Type**				
		SMUD			**Murray**		
Bergquam and Murray records, 1991-1999, SMUD	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Timer Controller problem Totals	**0**	**7**	**0**	**0**	**1**	**1**	**9**
-defective timer		2	0			1	3
-wrong on/off time		0	0		1		1
-current time incorrect		4	0				4
-unplugged from power source		1	0				1
Sensor failure Totals	**0**	**82**	**1**	**0**	**19**	**54**	**156**
-defective sensor		11	0		8	30	49
-defective collector sensor		30	0		2	7	39
-defective tank sensor		11	0		1	1	13
-collector sensor not properly attached/secured		5	0			1	6
-tank sensor not properly attached/secured		2	0				2
-improper connection method		2	0			5	7
-improper mounting location (collector)		0	0		5	3	8
-sensor not protected from environment		2	0		1	3	6
-sensor not installed (required)		1	0			1	2
-sensor and controller not compatible		0	0			1	1
-defective snap switch		0	0			1	1
-unknown problem		2	0		1		3
-defective temp gauge		1	1				2
-leaking at body of gauge		0	0		1		1
-defective transformer		15	0			1	16
Sensor wiring problem Totals	**0**	**29**	**0**	**0**	**7**	**22**	**58**
-defective sensor wiring		7	0		2	9	18
-defective wire connections		7	0		1	1	9
-open collector sensor wiring		2	0				2
-shorted collector sensor wiring		4	0		1		5
-open water heater sensor wiring		1	0				1
-shorted water heater sensor wiring		2	0				2
-sensor wires reversed		3	0			1	4
-sensor wire run not secured		1	0		1		2
-sensor wires not connected		0	0		1	1	2
-sensor wires crimped		0	0			1	1
-sensor wires chaffed from obstructions		0	0			1	1
-wiring insulation chewed off by rodents		1	0				1
-line cord problem		0	0			1	1
-roof wiring penetrations not sealed properly		0	0			1	1
-unknown problem		1	0		1	6	8
Solar Storage Water Heater problem Totals	**0**	**30**	**9**	**0**	**0**	**50**	**89**
-defective water heater		3	0			5	8
-tank fitting leak		10	2			7	19
-internal tank leak		3	0			8	11
-thermosiphon tank leak		0	1				1
-defective element		5	2			9	16
-defective thermostat		2	2			4	8
-defective thermostat wiring		0	0			1	1
-thermostat set too low		2	0				2
-thermostat tripped (overheating)		1	0			5	6
-voltage to water heater inadequate		0	0			1	1
-defective circuit breaker		0	0			1	1
-thermosiphon tank shell coming apart		0	1				1
-tank outer shell cracked		0	0			1	1
-white deposits in storage tank		1	0				1
-solar blocked from tank bottom calcification		0	0			1	1
-unknown problem		3	1			7	11

Sacramento Data

				System Type			
		SMUD				Murray	
Bergquam and Murray records, 1991-1999, SMUD	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Electric Auxiliary Water Heater problem	**0**	**27**	**1**	**0**	**0**	**7**	**35**
-defective tank		4	0			3	7
-internal tank leak		1	0				1
-defective element		8	1				9
-leak at element bolt		0	0			1	1
-defective thermostat		4	0			1	5
-thermostat tripped		2	0				2
-upper thermostat set too low		4	0				4
-lower thermostat set too low		1	0				1
-no electrical power to tank		1	0				1
-bad wiring on thermostat		0	0				0
-old water heater in efficient without solar		1	0				1
-not properly insulated		0	0			1	1
-unknown problem		1	0			1	2
Gas Auxiliary Water Heater problem totals	**0**	**1**	**1**	**0**	**0**	**14**	**16**
-defective tank		0	1				1
-internal tank leak		0	0			1	1
-defective thermocouple		0	0			1	1
-loose thermocouple connection		0	0			1	1
-failure to ignite		0	0			2	2
-pilot light off		0	0			3	3
-pilot valve defective		0	0			2	2
-unknown problem		1	0			4	5
Drainback tank problem totals	**0**	**16**	**0**	**0**	**0**	**3**	**19**
-defective tank		1	0				1
-tank leaks		2	0				2
-level indicator leaks		1	0				1
-tank is empty of fluid		1	0				1
-tank water level low		5	0			1	6
-improper fluid level		2	0				2
-tank overfilled		1	0				1
-unknown problem		1	0			1	2
-expansion tank problem		2	0			1	3
Pumps AC problem totals	**0**	**74**	**0**	**0**	**6**	**68**	**148**
-pump failure		4	0			2	6
-defective pump		35	0		4	36	75
-defective rotor		21	0				21
-defective gasket		1	0				1
-motor failure		0	0			2	2
-defective capacitor		0	0			1	1
-replaced cartridge		2	0			1	3
-bearing dry (need lubrication)		1	0				1
-leak in pump		0	0			3	3
-leak at pump connections		4	0			4	8
-loose pump mounting flanges		0	0			1	1
-air trapped in pump		1	0			5	6
-improperly installed		1	0				1
-required pump not installed		1	0				1
-unknown problem		1	0		1	10	12
-stuck shaft, impeller, or coupling		1	0				1
-pressure problem		0	0			1	1
-no pressure		0	0			2	2
-no collector loop pressure		1	0				1
-pressure too high, pool sweep runs with solar on		0	0		1		1

Sacramento Data	System Type						
		SMUD			Murray		
Bergquam and Murray records, 1991-1999, SMUD	**ICS**	**Pumped**	**Thermo**	**PV control**	**Pool**	**Unknown**	**Totals**
Heat exchanger problem Totals	**0**	**9**	**0**	**0**	**0**	**2**	**11**
-heat exchanger leak		4	0				4
-inefficient due to clogging		1	0				1
-isolated from system		1	0				1
-defective heat exchanger		2	0			1	3
-air in heat exchanger		0	0			1	1
-unknown problem		1	0				1
Heat transfer fluid problem Totals	**0**	**39**	**3**	**0**	**1**	**12**	**55**
-insufficient glycol mixture		17	1				18
-loss of chemical stability		1	0				1
-loss of fluid due to a leak		4	0		1	3	8
-fluid level low		1	0				1
-no fluid in system		1	1				2
-low pressure in loop		3	0				3
-no pressure in heat transfer loop		2	0			1	3
-recharge of fluid required		9	1			8	18
-wrong type of glycol used		1	0				1
Piping problems Totals	**0**	**1**	**0**	**0**	**1**	**2**	**4**
-entrapped air		1	0				1
-fluid leak in piping		0	0		1		1
-leak at roof piping penetration		0	0			2	2
Insulation exterior problem Totals	**0**	**33**	**2**	**0**	**0**	**19**	**54**
-defective insulation		6	1			2	9
-insulation deteriorating (non UV)		4	0			2	6
-uv protective foil tape deteriorating		17	0			3	20
-new insulation needed		1	0			6	7
-animals destroying insulation		1	0				1
-wrong type (foam/plastic) insulation used		1	0				1
-not used (required)		3	1			6	10
Valve, air vent problem totals	**0**	**14**	**0**	**0**	**0**	**44**	**58**
-defective air vent		13	0			26	39
-internal leak		1	0			2	3
-air in hot water line		0	0			1	1
-needs air vent		0	0			1	1
-leak at plumbing fitting		0	0			1	1
-not operating (air in system)		0	0			1	1
-not installed (required)		0	0			2	2
-inoperative due to freeze		0	0			9	9
-unknown problem		0	0			1	1
Valve, automatic draindown Totals	**0**	**72**	**0**	**0**	**0**	**9**	**81**
-valve defective		57	0			8	65
-does not open or close fully		1	0				1
-valve stuck in drain position		5	0				5
-valve stuck in fill position		3	0			1	4
-o-rings defective		1	0				1
-noisy operation		1	0				1
-unknown problem		4	0				4
Valve, anti-scald problem Totals	**0**	**1**	**0**	**0**	**0**	**2**	**3**
-defective valve		1	0				1
-needs internal rebuilding		0	0			1	1
-unknown problem		0	0			1	1

Sacramento Data	System Type						
		SMUD				Murray	
Bergquam and Murray records, 1991-1999, SMUD	ICS	Pumped	Thermo	PV control	Pool	Unknown	Totals
Valve, check problem Totals	**0**	**8**	**0**	**0**	**7**	**8**	**23**
-defective valve		4	0		5	2	11
-leaking		0	0			1	1
-valve stuck open - internal leak		1	0				1
-not installed (required)		2	0		2	1	5
-unknown problem		1	0			4	5
Valve, fill drain problem Totals	**1**	**8**	**0**	**0**	**2**	**4**	**15**
-valve defective		2	0		1	2	5
-internal leak at seals		1	0				1
-packing nuts loose		2	0				2
-not installed (required)	1	1	0		1	2	5
-unknown problem		2	0				2
Valve, freeze Totals	**0**	**1**	**8**	**1**	**1**	**18**	**29**
-valve defective		0	6	1		10	17
-valve leaking		1	1		1	6	9
-freeze plug problem		0	1				1
-unknown problem		0	0			2	2
Valve, isolation and supply Totals	**0**	**6**	**0**	**0**	**30**	**20**	**56**
-defective valve		2	0		7	10	19
-leak at seats		0	0			1	1
-improper setting (position)		2	0			2	4
-not installed (required)		1	0		4	2	7
-defective motorized pool valve		0	0		16		16
-isolation valve not sealing completely		0	0		1		1
-unknown problem		0	0		2	5	7
-internal leak at seal		1	0				1
Valve, mixing/temp problem Totals	**0**	**46**	**5**	**0**	**0**	**24**	**75**
-defective valve		18	3			8	29
-leaking		1	1			1	3
-needs internal rebuilding		15	0			12	27
-improper temperature setting		6	0			2	8
-loose packing nut		1	0				1
-stuck due to deposits		4	0				4
-required - due to water being too hot		0	0			1	1
-unknown problem		1	1				2
Valve T&P collector loop problem Totals	**0**	**7**	**7**	**0**	**0**	**15**	**29**
-defective collector valve		3	2			5	10
-leaking collector valve		1	0			1	2
-discharge not routed to proper location		0	0			2	2
-leaking at port - did not reseal after opening		0	0			1	1
-unknown problem		0	0			1	1
-defective water heater valve		3	4			2	9
-internal leak on water heater valve		0	1			3	4
Valve, Vacuum breaker problem Totals	**0**	**5**	**8**	**0**	**0**	**11**	**24**
-defective valve		5	5			4	14
-leaking		0	2			4	6
-valve has been plugged		0	0			1	1
-unknown problem		0	1			2	3
Summary	**14**	**585**	**51**	**3**	**173**	**504**	**1330**
Checksum							**1330**

SMUD Install Records

SMUD Solar Hot Water Installation Records

Total Models Installed 1991-2008

Model Number	Manufacturer	System Type	Total installed
300 series	Solahart	Thermosiphon	662
2001	American Solar Network	Pumped	146
444A	Copper Heart or Fafco	ICS	50
AETC	Alternate Energy Tech	Pumped	88
ASN	Anerican Solar Net.	Pumped/drainback	519
CC1B	Sage Copper Cricket	Thermosiphon	20
GOB1408	Heliodyne	Pumped	3
HP141080ACSHE	Heliodyne	Pumped	159
HV80	Heliodyne	PV pumped	1
JKP	Solarhart	Thermosiphon	246
PK20	Nippon	ICS	361
PT40	TCT	ICS	14
SX1000	Solmax	Pumped	707
SX3000	Solmax	Pumped	412
TE40C-80-1	Sun Earth	Pumped?	92
Unknown			3
Grand Total			**3483**

Total Installed by System Type 91-08

Sytem Type	Total installed
ICS	425
Pumped	2127
Thermosiphon	928
Unknown	3
total	3483

Total Installed by System Type 91-99

System Type	Total installed
ICS	423
Pumped	1889
Thermosiphon	907
Unknown	3
total	3222

NREL Review by System Type

NREL Survey (Data from Table: "Recurring Problems by System Type")

These data were not used in the Analysis

Survey of 221 Systems	SUMMARY BY SYSTEM TYPE				
Total Systems Surveyed	**0**	**200**	**15**	**6**	**221**
Type of System	**ICS**	**Pumped**	**Thermo**	**Not known**	**Totals**
Problem areas	**TOTAL OBSERVED PROBLEMS**				
Collector problems		22	1	2	25
Controller problems		37	0	1	38
Sensor Problems		64	3	2	69
Tank Problems		33	5	1	39
Pump Problems		68	0	0	68
Heat Transfer Problems		54	0	0	54
Piping problems		17	2	0	19
Valve Problems		42	6	1	49
Other		29	3	0	32
Totals	**0**	**366**	**20**	**7**	**393**
% systems with problems		183.0%	133.3%	116.7%	177.8%
Problem areas	**PROBLEMS AS A PERCENTAGE OF TOTAL**				
Collector problems		6.0%	5.0%	28.6%	6.4%
Controller problems		10.1%	0.0%	14.3%	9.7%
Sensor Problems		17.5%	15.0%	28.6%	17.6%
Tank Problems		9.0%	25.0%	14.3%	9.9%
Pump Problems		18.6%	0.0%	0.0%	17.3%
Heat Transfer Problems		14.8%	0.0%	0.0%	13.7%
Piping problems		4.6%	10.0%	0.0%	4.8%
Valve Problems		11.5%	30.0%	14.3%	12.5%
Other		7.9%	15.0%	0.0%	8.1%
Totals		100.0%	100.0%	100.0%	100.0%

NREL Review By Model

NREL Survey (Data from Individual graphs of problems for each system)

These data were not used in the Analysis

Survey of 221 Systems	SYSTEM MODEL										
	Solmax SX1000	**Solmax SX3000**	**ASN2**	**SunFamily PK20**	**Heliodyne HP141080**	**Solahart 302K**	**ASN 3**	**Solahart JKP1**	**AET C8040**	**Not known**	**Totals**
Total Systems Surveyed	**80**	**55**	**25**	**17**	**14**	**11**	**6**	**4**	**3**	**6**	**221**
Type of System	Pumped indirect	Pumped indirect	Drain-back	Pumped indirect	Pumped indirect	Thermo-siphon	Drain-back	Thermo-siphon	Pumped indirect	n/a	
Problem areas	**TOTAL OBSERVED PROBLEMS**										
Heat Transfer Problems	26	22	2	0	6	0	0	0	0	1	57
Sensor problems	31	3	2	0	8	0	2	0	2	2	50
Wiring Problems	15	0	0	0	0	0	1	1	0	0	17
Valve Problems	11	0	7	10	3	6	1	4	2	1	45
Insulation Problems	10	0	0	0	0	0	0	0	0	0	10
Controller Problems	24	20	8	6	3	3	0	0	0	0	64
Pump Problems	10	48	4	5	0	0	0	0	1	1	69
Collector Problems	16	3	8	2	3	0	0	0	2	3	37
Tank Problems	11	11	6	2	0	3	2	0	0	1	36
Piping Problems	6	0	0	0	0	0	0	0	1	1	8
Other	9	0	0	11	3	5	2	0	0	0	30
Totals	**169**	**107**	**37**	**36**	**26**	**17**	**8**	**5**	**8**	**10**	**423**
% problems per system	211.3%	194.5%	148.0%	211.8%	185.7%	154.5%	133.3%	125.0%	266.7%	166.7%	191.4%
Problem areas	**PROBLEMS AS A PERCENTAGE OF TOTAL**										
Heat Transfer Problems	15.4%	20.6%	5.4%	0.0%	23.1%	0.0%	0.0%	0.0%	0.0%	10.0%	13.5%
Sensor problems	18.3%	2.8%	5.4%	0.0%	30.8%	0.0%	25.0%	0.0%	25.0%	20.0%	11.8%
Wiring Problems	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	20.0%	0.0%	0.0%	4.0%
Valve Problems	6.5%	0.0%	18.9%	27.8%	11.5%	35.3%	12.5%	80.0%	25.0%	10.0%	10.6%
Insulation Problems	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%
Controller Problems	14.2%	18.7%	21.6%	16.7%	11.5%	17.6%	0.0%	0.0%	0.0%	0.0%	15.1%
Pump Problems	5.9%	44.9%	10.8%	13.9%	0.0%	0.0%	0.0%	0.0%	12.5%	10.0%	16.3%
Collector Problems	9.5%	2.8%	21.6%	5.6%	11.5%	0.0%	0.0%	0.0%	25.0%	30.0%	8.7%
Tank Problems	6.5%	10.3%	16.2%	5.6%	0.0%	17.6%	25.0%	0.0%	0.0%	10.0%	8.5%
Piping Problems	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	10.0%	1.9%
Other	5.3%	0.0%	0.0%	30.6%	11.5%	29.4%	25.0%	0.0%	0.0%	0.0%	7.1%
Totals	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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