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M-094

February 16, 2001

Pa. Public Utility Commission
Bureau of C.E.E.P.
P.O. Box 3265
Harrisburg, Pa. 17105-3265
Attn: Calvin Birge

Dear Mr. Birge:

Enclosed you will find ten copies of the 2[nd] year evaluation of PECO's Universal Services' Renewables Pilot Program.

If you have any question, please feel free to telephone me directly at 215- 841-6786

001369

Sincerely

Valeria C. Bullock, Manager
Universal Services

R-00973953

PECO ENERGY

RENEWABLES PILOT PROGRAM

ENGINEERING EVALUATION

Prepared for

PECO Energy – Universal Services

Valeria Bullock – Manager

December 12, 2000

By

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Table of Contents

Executive Summary

Overview

This Philadelphia area pilot program has refined a solar water heating (DHW) system design employing a solar electric (PV) powered pump and a solar fluid circulation loop using a non-toxic anti-freeze fluid (propylene glycol) and a heat exchanger. The current system specification and installation procedures have been refined through more than 120 installations in an urban context. These refined systems have a reasonable operational life of 20-30 years. This pilot shows annual savings for these systems to be in the range of 1,600-2,300 kWH/yr. Systems of this type are equally suitable for installation in any continental US location subject to significant winter freezing.

Major Findings

Long term Solar DHW System Savings Estimate from Monitoring

Hourly monitoring data from three solar DHW systems supports an estimate of annual savings for an average year. The two monitored Philadelphia area systems show savings of 2,480 kWh/yr for the larger system type and 2,310 kWH/yr for the other. The most predominant system type for this program showed annual average savings of 2,310 kWH/yr for a system operating against a full DHW load of 100 gal/day. This 2,310 kWH/yr savings represents the "best case" savings to be expected under the most favorable operating load.

Savings Estimate From Billing Data

Post retrofit billing data was only available on a small number of systems for a few summer months. Billing data on 12 installations shows Aug-September savings of 4.66. kWh/day(15,900 BTU/day). These savings inferred from billing data are lower than what was observed from the monitoring on a similar system. The billing derived savings are 15,900 BTU/day compared to the monitored savings of 22,400 for August. The billing savings are approximately 70% of the monitored savings. This lower savings observation can be explained by a possible pre/post occupancy change ("takeback") and by a possible lower average system usage, gallons/day, than the monitored system. This 70% ratio will be used here as a net to gross ratio to prorate the "best case" monitored savings of 2,310 kWh/yr to the observed net billing savings of 1,617 kWh/yr. This net to gross ratio should be regarded as a placeholder because it is based on a very limited sample of summer data. A more rigorous net to gross ratio can and should be derived from a full year of billing data from at least 50 systems as it accrues from the existing stock of 150 installations.

Solar Security Lights

This technology was dropped from the program when 6 months of monitoring showed that the specified security lights would not function in the winter and that low sun operation led to battery degradation. Custom designed military spec solar security lights are available, but at approximately ten times the cost of the lights tested in this program.

Solar System Configuration

Two system types are piloted in Philadelphia. The larger system uses a 64 ft2 solar panel area and an 80 gallon storage tank. The smaller (and predominant) system is significantly smaller and has less costly components than the larger system. It uses a 48 ft2 solar panel area and a 65 gallon storage tank. The two systems also use different heat exchanger types. Monitoring shows that the smaller system performs almost as well as the larger system. This is due to a combination of factors including 1) better performance by the heat exchanger in the smaller system 2) better piping insulation details for the smaller system, and 3) the smaller system is sized better for the observed hot water heating load..

Night Heat Losses

Both Philadelphia system types have a one-way check valve in the solar loop to limit the night heat losses by convection from the storage tank to the collectors on the roof. Both systems showed some evidence of such a convective loss mode, but monitoring data also shows the loss does not strongly effect the savings output. The Oregon system did not have the check valve, and it showed very clear evidence of the night-time convective loss mode. But this evident loss mode did not significantly reduce the savings of the Oregon system. For all three system types, the convective loss mode would be stopped every time there was a large DHW draw. The predominant (smaller) of the Philadelphia systems was the most resistant to night losses because of the configuration and placement of the heat exchanger at the bottom of the solar storage tank.

Early System failures

Five of the billing data cases showed no evidence of savings. Review of these cases showed all of them to be among the first systems installed by the program. Monitoring on the smaller Philadelphia system showed a system failure in mid summer traceable to residual trapped air and/or an undersized PV array for pump power. Both these events were symptoms of pumping failure and associated system overheating and loss of fluid. This failure mode has been corrected by vigorously circulating the system fluid during installation and by increasing the PV array size from 10 watts to 20 watts. All systems should be checked for proper operation after the first month of operation (preferably in the summer).

Solar System Orientation

Solar panels mounted on a 25-45 deg slope may be oriented over a wide range of directions. Orientations ranging from due South plus and minus 45 deg all show an annual solar exposure differing by less than 5%. Due East or West orientations for a 30 deg slope will have a 10% reduction in solar exposure which can be compensated for by upsizing the collector array from 48ft2 to 64 ft2.

Recommendations

Performance Follow-up

A rigorous estimate of billing savings for an average year should be derived by a statistical analysis of billing data for at least 50 of the 150 installed systems with at least a year of pre/post WH billing data. This rigorous savings estimate should be then be used as the net program savings instead of the "placeholder" net to gross ratio of 70% employed in this analysis.

System Performance Feedback and Diagnostic Checks

Cost effectiveness for this technology rests on a long system operating life, from 15-30 years. It is important to verify proper system operation during the first summer after installation and every few years thereafter. It is also important to provide system documentation which will allow the system to survive the two principal changes in the system's life: re-roofing, and change in the ownership or occupancy of the residence. System documentation, instrumentation installed with the system, and other installation details, and an installation follow-up check are all closely related. These should be carefully coordinated to facilitate a long system operating life.

System Technical Refinements

Recommendations pertaining to the performance of the systems include system sizing recommendations, the use of a 20 watt PV panel to power the pump, and solar collector orientation recommendations. All of these recommendations have already been incorporated into the program operations. In general, the technical refinements to this system have proceeded from a close working relationship between the evaluation contractor, the solar contractor, and the program management contractor. As regards ongoing technical improvements to the system and its installation procedures, it is important to preserve a broad working relationship between these parties and to maintain the expectation that feedback from ongoing operations will be a significant source of ongoing system improvements.

System Certification

The system used in this program is not formally certified by the Solar Rating and Certification Commission (SRCC) as a full system, even though the solar panels employed in the system are SRCC certified. A full SRCC system certification could help to bolster the credibility of the system in the eyes of various agencies and building inspection jurisdictions. Typically, an SRCC system certification is sponsored by a particular seller of solar equipment who packages the specified system components and sells the system as a designated SRCC system. In this case, the sponsor may be the solar contractor, PECO Energy, the program contractor, or another business entity. This pilot program has demonstrated a system and associated installation details with good performance in this area. The specifics are well enough known now to consider the application for an SRCC system certification.

Introduction

Project Description

The PECO Energy Renewables Pilot Project has been conducted pursuant to docket No. M-00991226 in the greater Philadelphia area served by PECO. It is directed to low income customers who qualify under LIURP income standards. The project involves the installation of specific solar energy equipment on qualifying customer residences. The underlying rationale for the project is to lower the energy bills of low income customers by demonstrating cost effective renewable energy applications. The project has been conducted in 1999 and 2000 per the timelines set forth in the tentative order in late 1998.

Initial project planning was started in December 1998. The project is due for completion by January 2001. Initial program activity consisted of equipment selection and associated cost effectiveness analysis. Initial project activity also included selection of project contractors: the evaluation contractor, and the prime project contractor, and installation subcontractors.

Evaluation Objectives

This document is an Engineering Evaluation; it is one of several components of the overall Project Evaluation for the PECO Energy Renewables Pilot Program. The objectives of this Engineering Evaluation are:

- to provide a measurement of the energy savings impact attributable to the technology installed by this program.
- to provide a technical review of the performance of the equipment being piloted in this project. This review is intended to identify avenues for performance improvement.

Organization of Report

This report is organized with an overall executive summary and discussions of the methodology and results in the body of the report. The discussions in the body of the report will refer as necessary to more detailed discussions or data included here in the appendices. The five appendices to this impact evaluation contain detailed summaries of the inspections, monitoring set up, monitoring data, and billing analysis information.

Engineering Evaluation Methodology

Overall Approach

The engineering evaluation was structured to proceed concurrently with project execution. This evaluation structure was chosen for use on a pilot project of this type in-order to provide the most timely feedback to project execution. Anticipating that the project may require mid-course refinements, the engineering evaluation employed in-depth equipment monitoring to evaluate performance in near real-time. The evaluation team provided interim results to the project execution team and helped to identify project problems early enough to effect timely project improvements. This engineering evaluation therefore divides logically into two principal components: Project evolution, and Savings estimation

Project Evolution

In the initial stages of the project, the evaluation team provided cost effectiveness screening and equipment selection feedback to the project execution team. Site inspections and equipment monitoring were employed on the earliest applications fielded by the project. Inspection reports and monitoring results were provided to the project execution and management teams on an approximate monthly basis.

Savings Estimation

This engineering evaluation uses equipment monitoring and billing analysis. These two different evaluation approaches are used together to estimate the energy savings of the project. Ideally, project savings would be evident in the billing histories of the project participants. But typically a billing based savings estimate would require several hundred participants in-order to attain a reasonable statistical resolution. The sample size available in this project may not be large enough or of sufficient duration to support such a statistically sound annual savings estimate at this time. However, there is sufficient billing data to estimate summer savings on a limited number of systems.

Therefore, a hybrid approach is employed with the calculation of both a monitoring based savings estimate, and a billing based savings estimate. Another significant component effort is the analysis of the monitoring data in an effort to the operation of the technology and its installation.

Data Sources

Site Inspection

Site inspections were conducted on 19 sites. These sites represent approximately 25% of the earliest installations. The site inspection process provided a forum for reviewing the installation process. Site inspection data is included here in Appendix A – Site Inspection Reports.

Monitoring Data

Five sites were monitored by logging hourly data on site performance variables. Two sites were solar security light sites, and three sites were solar DHW sites. There were 8-12 site performance variables at each site. The sites were monitored in enough depth to develop engineering models of key system components if necessary. This site monitoring is somewhat complex. A description of the monitoring rationale and the site monitoring details is included here in Appendix B – Monitoring Preparation and Installation Details. Monitoring results summaries for the two solar security light sites are included here in Appendix C – Solar Security Light Monitoring Summaries. Monitoring results summaries for the three solar DHW sites are included here in Appendix D – Solar DHW Monitoring Summaries.

Billing Data

Electric billing histories for 38 participants have been used to develop a billing based savings estimate. Billing data includes the meter read dates to permit association with temperature data. Most of the sites also have electric meter data for the DHW/Dryer enduse. Not all cases have the sub-metered data for the DHW/dryer enduse. Summaries of the analysis for each of the 38 billing data sites is included here in Appendix E – Billing data Summaries.

Temperature Data

Daily average temperature data for the last three years for Philadelphia have been used in the billing analysis. This data is ultimately from the NOAA weather database via the ezsim.com website national temperature database.

Long Term Solar Data

Long term average monthly horizontal solar insolation data is derived from the NREL solar database. The horizontal solar insolation data is transformed using the Maxwell estimator for solar insolation on an arbitrarily oriented surface.

Analysis Methodology For Monitored Data

Key Variables

A preliminary review of the monitoring data indicates that the key variables underlying a statistical model of the monitored performance will be:

- Net Solar output which includes the energy savings contributions from both the solar system and thermal gains/losses from the solar storage tank.
- Solar Incidence in the plane of the solar collectors
- Inlet water temperature
- DHW usage rate gallons/day

Calibrations and Corrections

Solar Pump Calibration – The flow rate for the solar loop has been derived by correlating the voltage at the solar pump with a visual reading of the flow meter in the solar loop. The co-relations used are:

- DHW 1 Flow gpm = (positive values) .14*voltage - .067
- DHW 2 Flow gpm = (positive values) .6462*voltage-1.23
- DHW 3 pre Jun 25 = (positive values) .224*voltage - .266
- DHW 3 post June 25 = (positive values) .298*voltage -.266

Solar Insolation – Solar insolation in the solar collector plane has been indirectly estimated by correlating the pump voltage (which varies with solar intensity) to a several day measurement of the solar insolation in the collector plane. The relationship between the solar insolation and the pump voltage is well defined as shown in Figures 1and 2.

Figure 1. Solar Correlation DHW 1

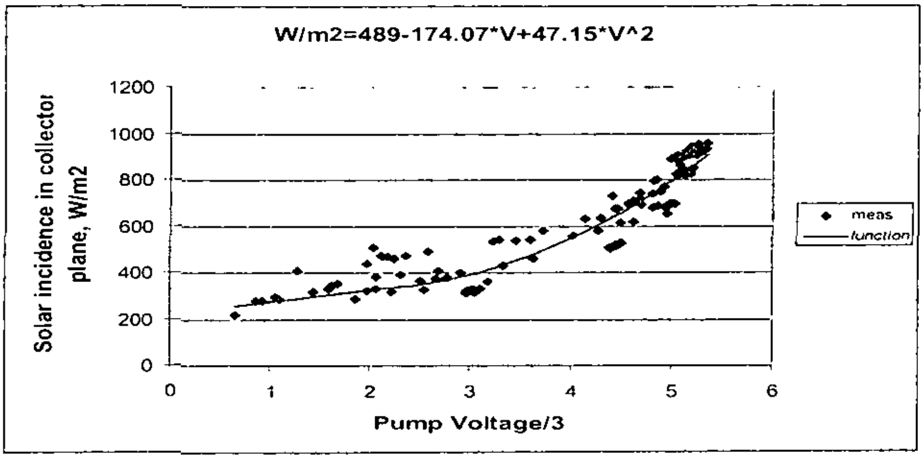
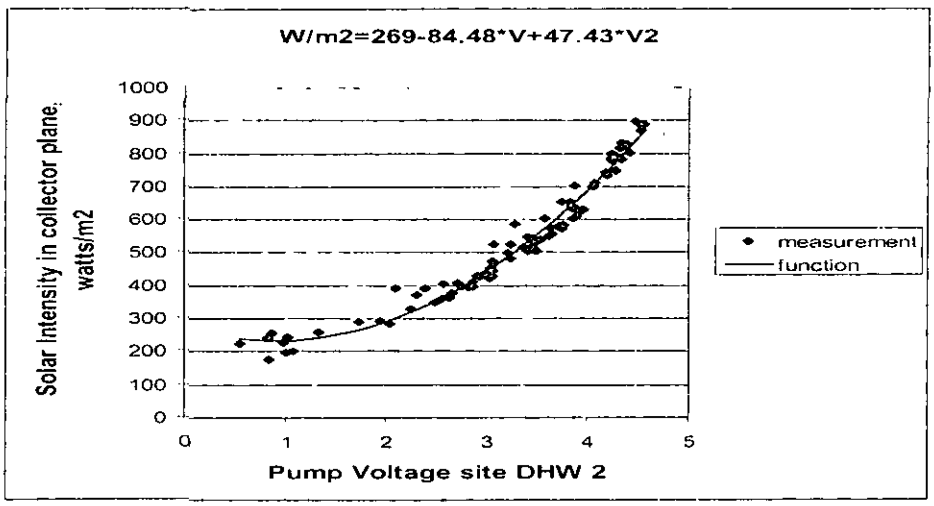
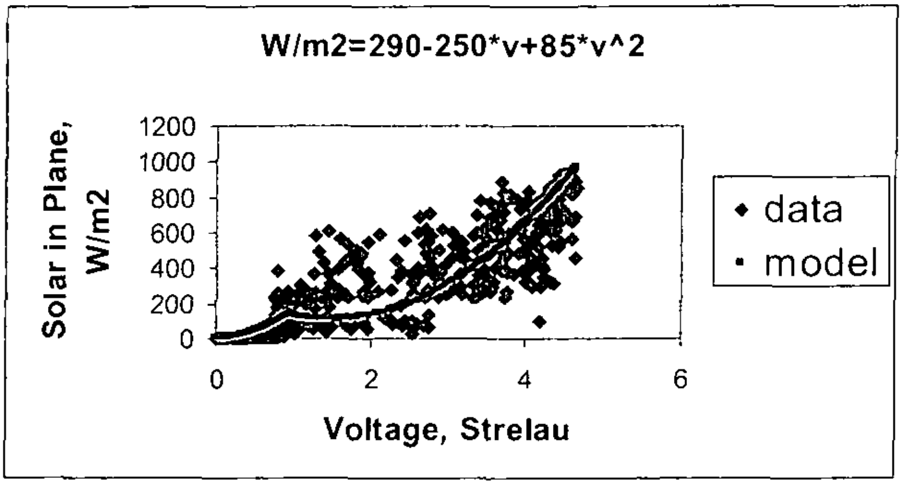


Figure 2. Solar Correlation DHW 2



The solar correlation for site DHW 2 was also used for the other Philadelphia site, DHW 3 until site DHW 2 was decommissioned in mid September 2000. Solar data for site DHW 3 for October and later has been provided by a correlation between August voltage date at site DHW 3 and the solar estimates for site DHW 2. This correlation, shown in Figure 3 is much more ragged than the co-relations in the other two figures. This reflects a marked difference due to variable cloudiness between the hourly solar intensity observed by locations on the opposite sides of Philadelphia. Note in Figure 3 that there is reasonable agreement between these sites during the clearest weather.

Figure 3. Solar Forecast Model for Site DHW 3



Fluid Properties – The volumetric mass and heat capacity of the working fluid (50% water/propylene glycol) are necessary in-order to calculate the heat absorbed in the solar loop. The volumetric density of the working fluid was directly measured as 8.44 lbs/volume gallon. The heat capacity of the working fluid was derived from manufacturers data as .85 BTU/lb.

Regression Procedure

In general all monitoring exercises encounter environmental conditions that differ from the long term average conditions. Often a monitoring exercise will not last for an entire year. In this case, the monitoring exercises were not of a year duration, and the spring and summer of 2000 was wetter and less sunny than the long term average conditions. In a case such as this, the monitoring results can only be generalized to an estimate of long term annual savings by means of an engineering model or a statistical regression model.

In this case a preliminary review of the summary monitoring data showed that system output varied significantly with solar intensity, and with inlet water temperature. The monitoring data was of sufficient resolution to support the solution for two or three unknowns. In this analysis the regression model has the common linear form[1]:

- Savings = x1 +x2*inlet temp +x3*solar+x4*inlet temp*solar

[1] Physically DHW usage is also a significant determinant of savings. It is not used in this regression because the value of this variable was reasonably constant throughout the monitoring exercise, and there were insufficient monthly data points to resolve this variable confidently by regression from this dataset

In the regression procedure used here the first step is to find a model of the monitored system results in terms of identified key environmental variables. This model is then used to forecast the performance of the system over a long term average year.

Normalized Long Term Savings Estimate

In-order to forecast the savings model to a long term savings estimate, the long term environmental conditions need to be identified. For this exercise the long term solar and inlet water temperatures need to be identified.

Long Term Solar Insolation – the long term horizontal solar insolation for Philadelphia has been drawn from the database of the National Renewable Energy Laboratory(NREL). The horizontal solar insolation is further transformed to an estimate of the solar insolation on a 30 deg south facing surface.

Monthly Inlet Water Temperatures – The long term monthly average inlet water temperatures for a full year have been synthesized from the part year monitoring results for sites DHW 2 and DHW 3.

The long term solar and water conditions are presented in Table 1. Solar insolation is in BTU/ft2/day and water temperature is deg F.

Table 1. Long Term Solar and Water Temperatures

	Solar	Inlet T
Jan	838	44
Feb	1056	43
Mar	1286	47
Apr	1489	52
May	1650	62
Jun	1770	68
Jul	1748	74
Aug	1609	73
Sep	1421	70
Oct	1191	65
Nov	812	55
Dec	698	46

Figures 4 and 5 show how these long term conditions compare to the monitored conditions.

Figure 4. Inlet Water Temperatures

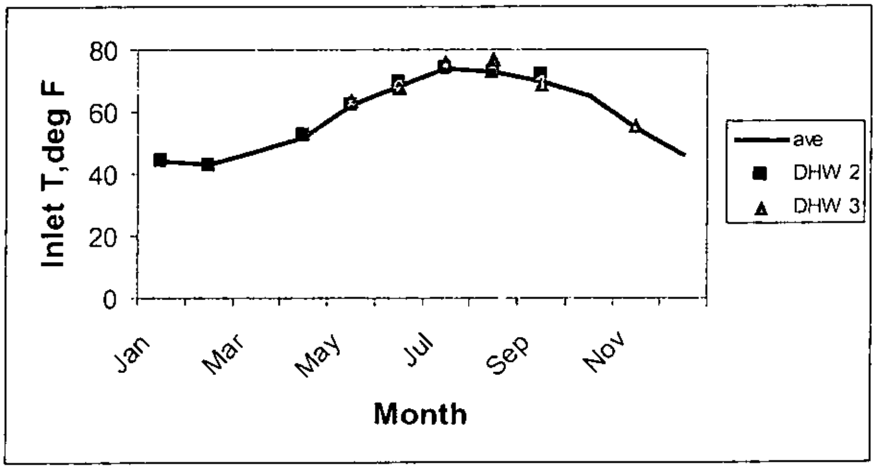
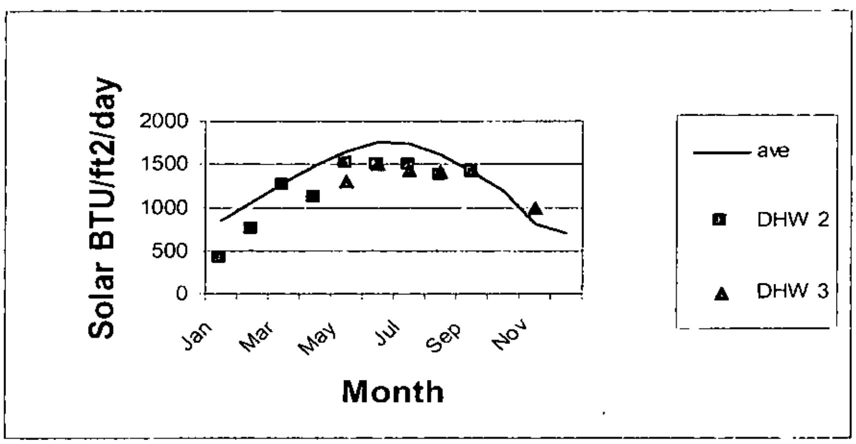


Figure 5. Monthly Solar Insolation @30 deg South Slope



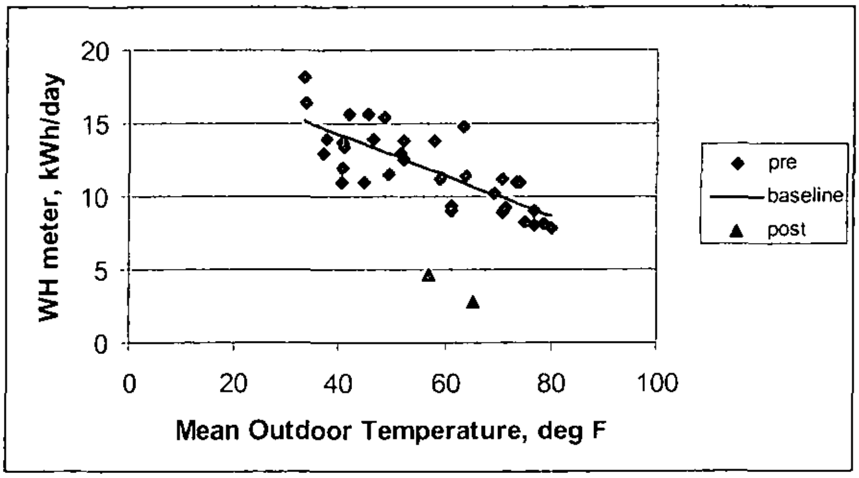
Note in Figure 5 that the solar conditions for spring/summer 2000 are much less than the long term average solar conditions.

Analysis Methodology For Billing Data

The billing data available for this analysis is of two types 1) electrical usage by DHW and Dryer (referred to here as WH data), and 2) electrical usage by all other uses. The availability of the WH data provides an opportunity for an accurate billing based energy savings estimate.

Each month of usage data is associated with a mean outdoor temperature calculated for the specific days of the billing interval. It shows a clear variation with mean outdoor temperature as illustrated in Figure 6..

Figure 6. Pre and Post WH billing Data



The billing analysis first characterizes the pre-retrofit energy use by a baseline function statistically fitted to the pre retrofit data. A similar function is then statistically fitted to the post retrofit data.[2]

After the pre and post energy uses are defined by functions, the savings for any particular average monthly temperature are defined as the difference between these functions at that temperature. Thus a function of savings vs average monthly temperature is created.

The long term average month by month savings are then estimated by evaluating the savings function over the long term average outdoor temperatures for Philadelphia which are included here in Table 2.

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[2] The specific analytical form of the functions fitted to the data needs to be determined by a preliminary review of the data. In efforts to estimate solar savings from billing data a broken line function similar to a PRISM analysis is used. In this case the WH data permits the use of the simpler straight line function.

Table 2. Long Term Average outdoor Temperatures deg F

Month	deg F
Jan	28.6
Feb	31.3
Mar	41.2
Apr	51.6
May	61.8
Jun	70.9
Jul	75.7
Aug	74.1
Sep	66.4
Oct	54.7
Nov	44.4
Dec	33.6

This general method cannot be fully applied in this analysis at this time because there is insufficient post retrofit data to define the post retrofit energy use function. However, this limited data set will be examined to estimate a summer only savings which can be supported by the currently existing data.

Energy Savings from Monitored Data

Summary and Discussion

The monitored data supports estimates of Philadelphia area long term savings of 2,468 kWh/yr for site DHW 2 and 2,310 kWh/yr for site DHW 3. Long term savings for site DHW 1 (the Oregon site) were not derived. The data shows higher than expected savings in winter months due to the low inlet water temperature and the associated thermal gains by the solar storage tanks. Since most of the program installations are systems of the type designated here as DHW 3, The mean savings to be attributed to the solar equipment deployed in this program should be 2,300 kWh/yr. It should be noted that these savings are specific to the greater Philadelphia area. This savings estimate should also be regarded as an upper bound savings estimate because it corresponds to a system with a DHW load of 80-110 gallons/day. If the DHW load is low ,20-40 gallons/day, as from infrequent hot water use for a single person family, then the solar savings will be lower than those reported here.

Monitoring Results – DHW 1

Summary of monitored Data

Table 3 gives a summary of the monitored data for site DHW 1. This was the first site monitored as a checkout of the monitoring procedure and as a test of a potential simplification of the system. Monitoring for this site is limited to the operation of the solar DHW system and does not include monitoring of the output of the backup DHW tank which is included in the monitoring of DHW 2 and DHW 3. Therefore for DHW 1 there are no summary results for Mean DHW BTU/day or for DHW tank loss. Most of the variable names used in monitoring summaries are self-explanatory, however several variables should be explicitly defined:

- Mean DHW BTU/day – This is the thermal energy output of the backup DHW tank downstream of all controls and tempering valves. It refers to the energy required to raise the water temperature from the instantaneous inlet temperature to final instantaneous outlet water temperature of the whole DHW system.
- Mean Solar BTU/day – This is the thermal energy emerging from the solar storage tank downstream of any tempering valves on the solar storage tank. It refers to the energy required to raise the water temperature from the instantaneous inlet water temperature to the instantaneous temperature of the water emerging from the solar storage tank and its controls.

- Solar Contribution – This is the fraction of the DHW load provided by the solar water heater. Specifically, it is the ratio (Mean Solar BTU/day)/(Mean DHW BTU/day).
- HX Performance – This is a measure of the overall heat exchanger operation. It is broadly defined to include the effects of the physical placement of the heat exchanger relative to any operational thermal gradients in the solar storage tank. It is specified in this manner to facilitate its use in a performance simulation model.
- DHW tank Loss – This is a measure of the mean thermal losses from the backup DHW tank.
- Solar Tank Loss – This is a measure of the mean thermal losses from the solar storage tank.
- Incident Solar – This is the intensity of the solar incident on the 30 deg South sloping surface of the solar collectors. This information is indirectly derived by correlation of short term measured solar in the collector plane with the measured pump voltage.
- Mean Efficiency – This variable is a measure of the overall energy conversion efficiency from incident solar energy on the collectors to the energy savings tabulated as the Mean Solar BTU/day.

Table 3. Summary Monitoring Data for System DHW1

Month		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Duration	days	30.1	30.5	14.5	37.9	26.0	19.0	38.3	30.0	31.0	27.6
Mean Inlet Temp	deg F	57.2	57.7	58.4	59.4	59.1	59.2	58.6	59.1	57.3	55.9
Mean Outlet Temp	deg F	60.8	72.7	84.6	92.0	110.1	110.1	114.3	96.9	75.6	60.4
Mean DHW usage	gal/day	84.9	73.2	67.6	78.3	76.7	61.4	64.1	71.3	82.0	80.6
Mean DHW BTU/day		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean Solar BTU/day	BTU/day	2,599	9,152	14,796	21,234	32,606	26,066	29,781	22,443	12,498	3,073
Solar Contribution		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HX Performance	BTU/deghı	97.6	90.5	91.3	91.3	72.4	77.3	78.7	81.5	80.6	105.6
DHW tank factor		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar tank factor		1.3	0.9	0.9	1.0	1.1	0.9	1.1	1.1	1.2	1.2
Incident Solar	BTU/ft2/da	215	667	923	1,156	1,721	1,661	1,670	1,181	700	250
Mean Efficiency		20%	23%	27%	31%	32%	26%	30%	32%	30%	21%

Discussion of Summary Data – These data show a DHW usage of approximately 80 gallons/day, typical for this size family. Notably the inlet water temperature is almost constant year round. This is because the water source is a deep well. In the winter this well water is warmer than the outside and this tends to lower the winter operating efficiencies. There is also evidence that the solar tank was gaining heat from its surroundings during the coldest months of winter.

Monitoring Results – DHW 2

Summary of Monitored Data

Table 4 gives the summary monitoring data for site DHW 2. The same variable definitions apply to this site as defined above for site DHW 1. Note that for the month of March there is missing data. This is due to a faulty connection to the flow transducer.

Table 4. Summary of Monitoring Data System DHW 2

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Duration	days	32.7	31.5	38.9	20.1	38.0	24.4	21.3	31.3	26.4
Mean Inlet Temp	deg F	44.3	42.6	#DIV/0!	52.3	62.2	69.0	73.8	72.5	71.9
Mean Outlet Temp	deg F	109.8	110.5	#DIV/0!	109.7	110.3	110.5	110.7	111.0	110.8
Mean DHW usage	gal/day	109.6	84.3	0.0	96.5	98.9	109.0	97.6	106.4	111.4
Mean DHW BTU/day		59,809	47,725	0	46,186	39,686	37,698	30,013	34,163	36,097
Mean Solar BTU/day	BTU/day	14,370	16,168	0	23,272	25,229	25,757	22,822	22,376	23,817
Solar Contribution		24%	34%	#DIV/0!	50%	64%	68%	76%	65%	66%
HX Performance	BTU/deghı	400.5	310.8	191.0	162.1	120.2	128.3	104.4	120.4	131.8
DHW tank factor		0.83	0.82	0.00	0.83	0.85	0.86	0.86	0.85	0.86
Solar tank factor		1.15	0.88	0.00	0.97	0.84	0.90	0.92	1.00	0.96
Incident Solar	BTU/ft2/da	403	736	1,246	1,110	1,501	1,486	1,492	1,357	1,420
Mean Efficiency		52%	42%	42%	36%	33%	32%	28%	28%	29%
Electric standby	BTU/day	12,070	10,650	34,873	9,750	7,243	6,256	5,055	6,173	6,111

Discussion of Summary Data - The mean inlet water temperature at this site exhibits a wide seasonal swing from about 42 deg F in the winter to 74 deg F in the summer. The low inlet water temperatures in the winter lead to much improved winter performance because the solar storage tank gains heat from surroundings and the low temperature water fed to the solar collectors leads to a good solar collection efficiency. Note the high efficiency in the winter. These efficiencies would be unusually high for solar systems except that in this case, the efficiency is based on the collected solar energy and the energy absorbed by the solar storage tank.

Regression Based Savings Model

Table 5 gives the data used to develop the regression model of the monthly savings as a function of inlet water temperature and incident solar. The incomplete March data was omitted from the regression.

Table 5. Regression Data for Site DHW2

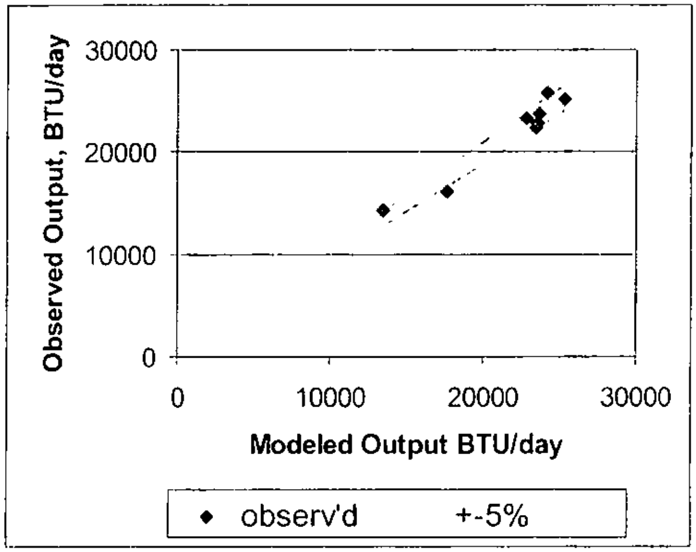
	solar	inlet	observed	model
Jan	403	44.3	14,370	13,461
Feb	736	42.6	16,168	17,576
Mar	1246			
Apr	1110	52.2	23,272	22,772
May	1510	62.2	25,229	25,299
Jun	1486	69	25,757	24,193
Jul	1492	73.8	22,822	23,528
Aug	1357	72.5	22,376	23,414
Sep	1420	71.9	23,817	23,623
Oct				
Nov				
Dec				

The regression model derived from this data is:

Mean Solar BTU/day = -11,039+433.7*Inlet+30.24*Solar-.39*Inlet*Solar

As a check on the validity of this model over the range of the variables, the modeled savings are plotted against the observed savings in fig 7. This figure shows agreement between the modeled and observed data within about 5%.

Figure 7. Performance of Model DHW2



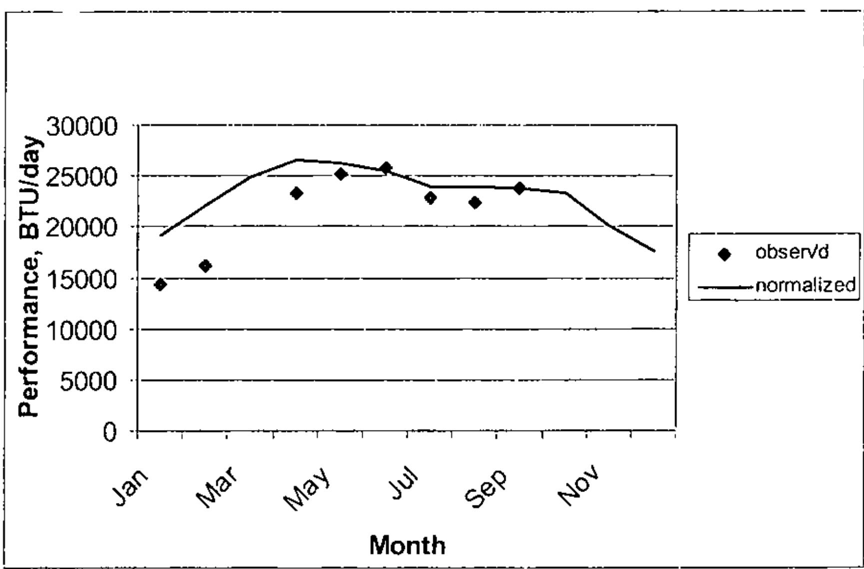
Normalized Savings Estimate

The regression model is exercised over the long term values for inlet and solar variables to give an estimate of the long term monthly performance. The resulting performance estimates are presented in Table 6., and presented graphically in fig 8. Table 6 shows annual savings of 2,468 kWh/yr for systems of this type in Philadelphia.

Table 6. Long Term Savings Estimate for Site DHW 2

	Solar	Inlet T	Observed	Model
Jan	838	44	14,370	19,141
Feb	1056	43	16,168	21,995
Mar	1286	47		24,868
Apr	1489	52	23,272	26,619
May	1650	62	25,229	26,205
Jun	1770	68	25,757	25,458
Jul	1748	74	22,822	23,918
Aug	1609	73	22,376	23,880
Sep	1421	70	23,817	23,846
Oct	1191	65		23,246
Nov	812	55		20,108
Dec	698	46		17,608
Annual average daily gain, BTU/day				23,074
Annual average daily gain, kWh/day				6.76
Long term annual savings, kWh/yr				2,468

Figure 8. Long Term Solar Performance DHW 2



It is important to note in Table 6 that the long term savings for the spring and summer months are considerably larger than the savings observed in the monitoring data. This is due to the fact that the spring and summer of 2000 were much wetter and less sunny than for an average year.

Monitoring Results – DHW 3

Summary of Monitored Data

Table 7 gives the summary monitoring data for site DHW 3. The same variable definitions apply to this site as defined above for site DHW 1. Note that for the months tabulated as June, July, and August exhibit the effects of a faulty electric power transducer. This is due to an undetected misalignment of the DHW power transducer. The failed electric measurements lead to erroneous measurements of the electric standby losses for these months.

Table 7. Summary of Monitoring Data for System DHW 3

Month		May	Jun	Jul	Aug	Sep	Nov
Duration	days	22.2	36.0	36.8	41.5	21.9	25.0
Mean Inlet Temp	deg F	63.4	67.5	75.8	76.9	68.6	55.4
Mean Outlet Temp	deg F	127.9	122.5	117.7	118.5	118.3	118.9
Mean DHW usage	gal/day	102.8	107.9	78.4	81.8	93.2	109.1
Mean DHW BTU/day		55,217	49,406	27,368	28,349	38,532	57,693
Mean Solar BTU/day	BTU/day	19,066	19,147	23,434	25,392	25,118	16,709
Solar Contribution		35%	39%	86%	90%	65%	29%
HX Performance	BTU/deghr	233.3	166.3	169.1	175.6	192.0	190.0
DHW tank factor		0.82	2.58	1.17	1.12	0.78	0.86
Solar tank factor		0.73	0.99	1.00	0.98	1.01	1.09
Incident Solar	BTU/ft2/da	1,311	1,510	1,428	1,407	1,426	985
Mean Efficiency		31%	25%	35%	39%	38%	36%
Electric standby	BTU/day	8,440	-30,232	-3,934	-2,957	8,651	9,301

Discussion of Summary Data – The months of May and June show operation with a 10 Watt PV panel. In the month of June the system ceased to operate and was down for two weeks. Review of the monitoring data showed that for the months of May and June the system was starting with very high temperatures and very slow pumping on hot days. This operation somewhat repressed the performance for these months. The system failure was traced to residual air in the system and also to weak pumping on very sunny days. As a further remedy the PV panel on this system and other similar systems was increased from 10Watts to 20 Watts. The later months show operation with a 20 Watt PV panel.

Regression Based Savings Model

Table 8 gives the data used to develop the regression model of the monthly savings as a function of inlet water temperature and incident solar. The six months of summary data from Table 7 have been re-aggregated into eight measurements in-order to increase the range of variable expression and strengthen the regression. The re-aggregated data omits the two weeks of non-operation in June 2000.

Table 8. Regression Data for Site DHW 3

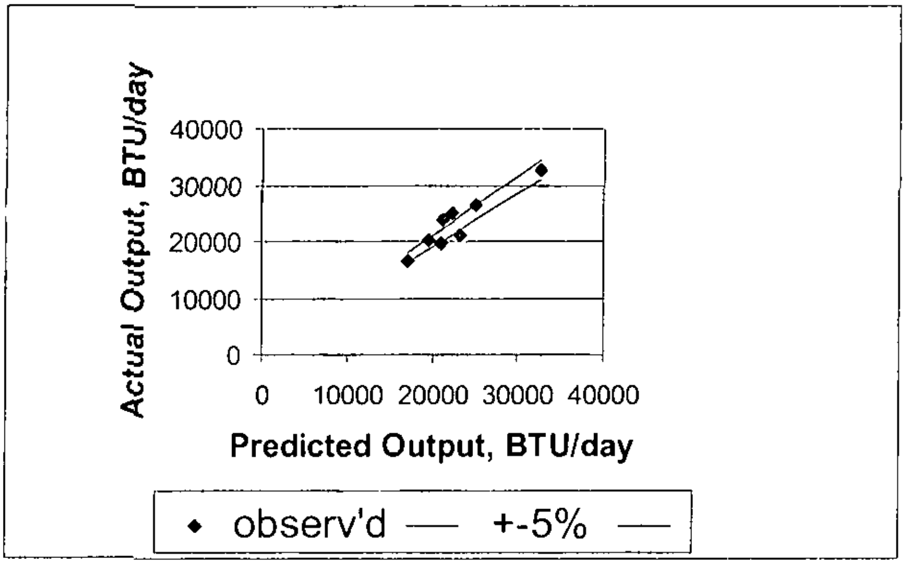
	solar	inlet	observed	model
Jan				
Feb				
Mar				
Apr	1283	63.2	20,376	19,569
May	1555	64.8	21,234	23,249
Jun	1883	74.4	32,620	32,629
Jul	1300	76.3	19,679	20,939
Aug	1307	76.8	24,070	21,139
Sep	1494	76.2	26,458	25,141
Oct	1426	68.6	25,118	22,263
Nov	985	55.4	16,709	17,193
Dec				

The regression model derived from this data is:

Mean Solar BTU/day = 60,825-893.8*Inlet-35.9*Solar+.76*Inlet*Solar

As a check on the validity of this model over the range of the variables, the modeled savings are plotted against the observed savings in fig 9. This figure shows agreement between the modeled and observed data within about 5%-10%.

Figure 9. Performance of Model DHW 3



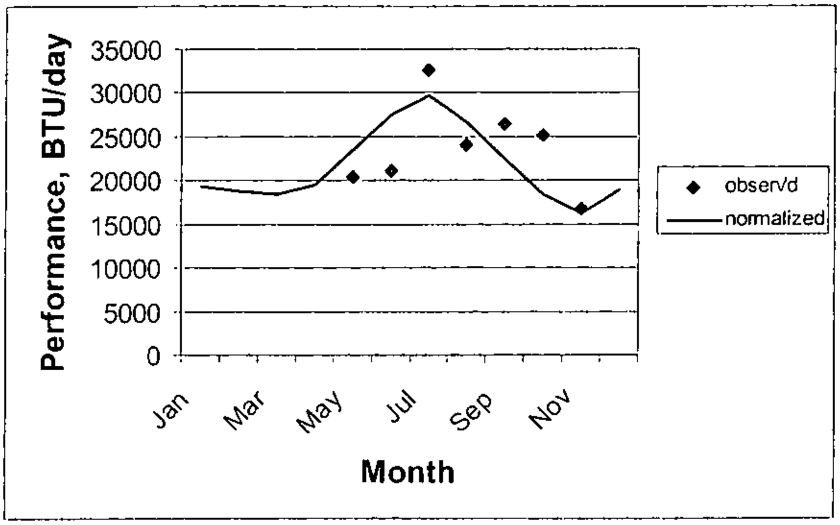
Normalized Savings Estimate

The regression model is exercised over the long term values for inlet and solar variables to give an estimate of the long term monthly performance. The resulting performance estimates are presented in Table 9., and presented graphically in fig 10. Table 9 shows long term annual savings of 2,310 kWh/yr for systems of this type in Philadelphia.

Table 9. Long Term Savings Estimate for Site DHW 3

	solar	inlet T	observed	model
Jan	838	44		19,279
Feb	1056	43		18,798
Mar	1286	47		18,330
Apr	1489	52		19,415
May	1650	62	20,376	23,497
Jun	1770	68	21,234	27,484
Jul	1748	74	32,620	29,704
Aug	1609	73	24,070	26,612
Sep	1421	70	26,458	22,442
Oct	1191	65	25,118	18,488
Nov	812	55	16,709	16,271
Dec	698	46		18,919
Annual average daily gain, BTU/day				21,603
Annual average daily gain, kWh/day				6.33
Long term annual savings, kWh/yr				2,310

Figure 10. Long Term Solar Performance Site DHW 3



It is important to note in Table 9 that the long term savings for the spring and summer months are considerably different than the savings observed in the monitoring data. This is due to the fact that the spring and summer of 2000 were much wetter and less sunny than for an average year. It is also due to the fact the data were re-aggregated into 2-3 week segments that are more extreme in mean solar than average monthly solar.

Energy Savings from Billing Data

Summary and Discussion

At the time of this analysis, there was a very limited sample of review-able cases. Even so, the analysis of this limited data sample shows that the DHW end-use data,(WH) can support a very good estimate of savings with the cases that are expected to be available within a year.

Using the data available at the present time, a savings of 4.66 kWh/day is estimated for the summer operation of the solar DHW systems. The 95% confidence limit on this measurement is +- .87 kWh/day. This is a very good confidence limit to be achieved from such a limited sample.

The reviewed billing data showed evidence of system failure on systems installed early in the project and not yet remedied.

The savings estimated in this billing analysis are less than the savings estimated from the monitoring analysis. This difference can be traced to two causes:

- Some cases show a low DHW usage which will manifest lower savings than for a system at a site with a high DHW usage such as the ones that were monitored.
- In some cases participants can be expected to use more hot water because they perceive that the hot water is "free". This is the classic takeback effect common in all measurements of savings by efficiency measures.

Description of Data

Classification of Available Billing Data

The data available for this billing analysis is limited because the analysis was undertaken on schedule at a time when only a third of the project systems had been installed. Where sufficient pre retrofit billing data was available, there were typically only one or two months of post retrofit billing data. After a year has elapsed a useful sample size of the order of 100 cases will be accrued.

A strong advantage of this billing data is that most cases include sub-metered ,WH, energy use for the DHW and dryer enduses only. This type of sub-metered data has a very good signal to noise ratio and will support a good savings measurement from as few as 50-100 usable cases. For this analysis, billing data for the pre retrofit period of up to a year prior to installation is used to establish a pre-retrofit baseline. Since the maximum sample size available to this analysis is of the order of 100 cases, a confident savings estimate will need to be based on the WH data.[3] Therefore, only cases with sufficient pre retrofit WH data will be used in this analysis.

A classification of the cases used in this analysis is given in Table 10.

Table 10. Distribution of Billing Analysis Cases

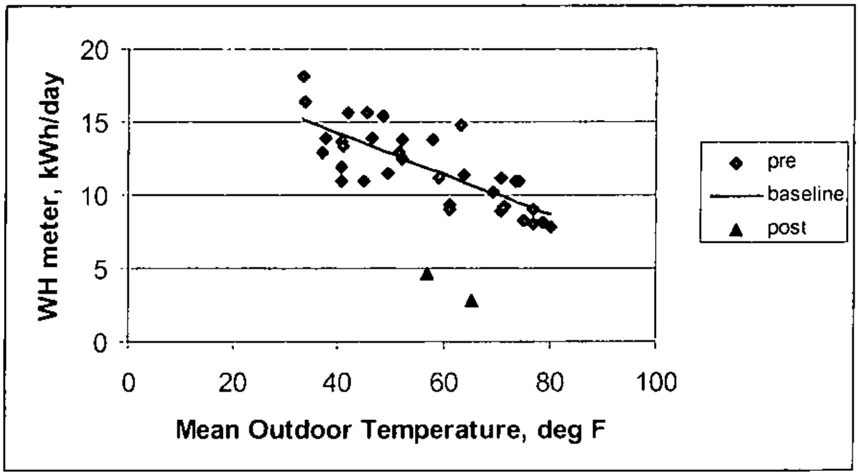
Total cases examined	**38**
cases with pre WH data	**25**
cases with post WH	**17**

Example of Data Analysis

An example of this analytical method is given in Figure 11. This figure illustrates the pre retrofit data and the baseline function fitted to it. The savings illustrated in this figure are the difference between the pre retrofit function and the post retrofit points. Where sufficient post retrofit data exists, a function is also fitted to the post retrofit data, and this function is used to estimate the savings to be seen in an average year.

[3] Savings can also be estimated from whole building billing data, but there is much more occupancy variation in this data. Prior experience with determination of savings from whole building billing data has showed that a sample size of a few hundred is necessary to detect savings of the magnitude expected of solar savings.

Figure 11. Example Savings Analysis



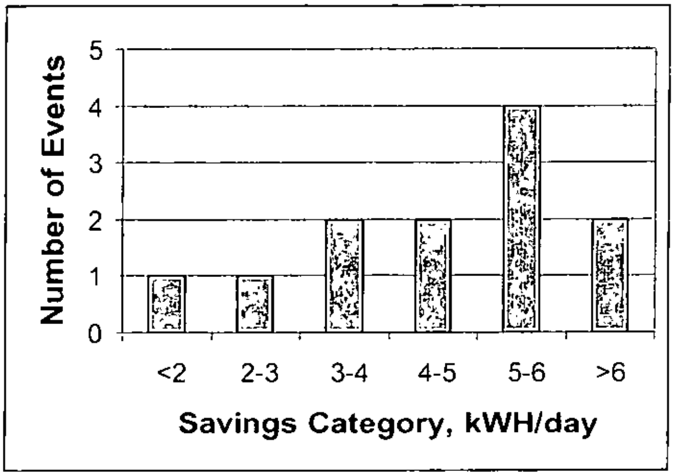
Summer Savings Estimate

For this limited data sample, with only one or two post retrofit points, an abbreviated savings estimate is made. At a later time (summer 2001) a full annual savings estimate can be made. For this analysis, a savings estimate is for summer data only where mean outdoor temperatures exceed 60 deg F. This summer estimate is simply the difference between the mean pre and post data for all points with temperatures greater than 60 degF.

In this analysis there are 17 case with sufficient pre and post WH data for a summer savings estimate. Of these 17 cases there are five cases which show no savings or negative savings. Discussions with program staff revealed that all these failed cases were very early installations that were not remedied soon enough to give valid post retrofit data. Therefore, for the purposes of estimating mean savings these cases are not included in the statistical analysis.

Of the remaining 12 cases, the savings are distributed as in Figure 12.

Figure 12. Summer Savings Distribution



The statistical summary of this limited data sample is given in table 11.

Table 11. Savings Results

Mean Savings kWh/yr	**4.66**
lower 95% confidence	**3.79**
upper 95% confidence	**5.54**

Improvements to Savings Estimate

The fundamental data underlying this estimate is of very good quality. The only limitation on this data is the available number of cases at the time of the analysis. It is probable that by the summer of 2001, a sample of the order of 100 valid cases will be available to analysis.

It is evident from the relatively tight confidence limits on this small sample, that the WH data has a very good signal to noise ratio. A data sample of 50-100 cases would be able to produce an estimate with a precision of approximately 10% at a confidence level of 90%.

Solar Security Lights

Two solar security light installations were monitored in the summer and fall of 1999. These lights operated well in the long summer days and short summer nights. But by late fall, the storage battery voltage on these lamps fell to low and self destructive levels, and the internal logic of the lamps put them into a long term shut down state. These lights will not operate in a security light context in the winter in Philadelphia. It was recommended that this technology not be used in the program. See Appendix C for specific details.

Solar Orientation

The ideal orientation of solar collectors has long been a subject of engineering discussion. A change in orientation will change the solar insolation received from month to month. In principle there is an ideal orientation that will lead to a maximum annual solar.

Early inspections showed some cases of solar collectors mounted on racks at a different angle than the roof plane which looks awkward and detracts from the acceptability of this technology. In addition the urban context of this program offers limited orientation opportunities. Therefore, solar insolation calculations for a wide range of orientations are presented in table 12..

Table 12. Solar Insolation BTU/ft2/day for Tilted Surfaces @ Philadelphia

	horizontal	20 deg S	45 deg S	20S,45E	45S,45E	20 deg EorW
Jan	620	783	884	728	771	607
Feb	870	1016	1070	971	982	861
Mar	1190	1281	1241	1242	1181	1157
Apr	1520	1531	1375	1526	1392	1485
May	1760	1721	1489	1721	1520	1702
Jun	1930	1858	1582	1872	1641	1879
Jul	1880	1830	1567	1829	1603	1813
Aug	1670	1664	1472	1661	1497	1622
Sep	1350	1428	1354	1389	1298	1306
Oct	1000	1153	1196	1103	1104	984
Nov	640	771	838	725	744	624
Dec	520	653	735	608	644	511
Average	1246	1307	1234	1281	1198	1213

Table 12 shows that surfaces sloped at from 20 to 45 deg will all get a similar solar insolation for a wide range of azimuths. In general, it is reasonable to mount the collectors parallel to the roof plane as long as the roof faces south within +or- 45 deg. Table 12 also shows that even west or east facing orientations will get adequate solar insolation if the roof is not too steeply sloped.

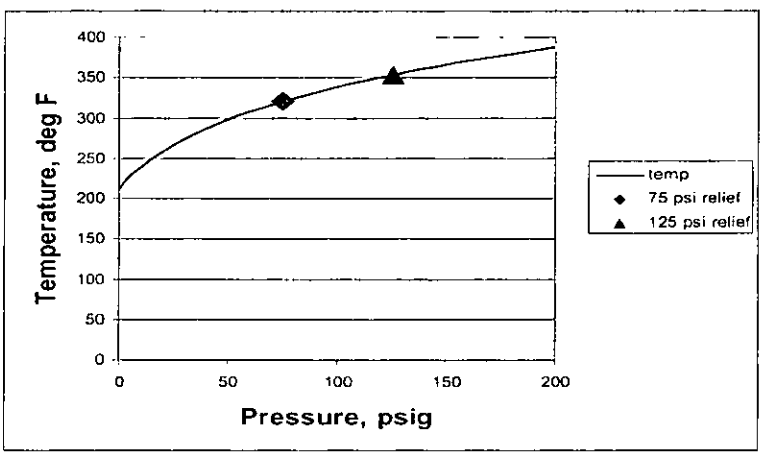
PV Panel Sizing and System Failures

The pumps for most of the installations in the program are nominally 10 Watt pumps. Initially these pumps were powered by a 10 Watt solar panel. However this 10 Watt solar panel only produces 10 Watts at full sun. Monitoring showed that in the morning the pump startup was slow.

The monitored system, DHW 3, showed that on very sunny days the first morning temperatures of the returning solar fluid were very high, in the range of 200 deg F. Eventually the system failed, discharging most of its fluid through the 75 psi pressure relief valve. This type of event appears to have happened on several of the early systems. An explanation for this event is that slow early pumping (and small amounts of residual air trapped in the system) led to very slow or no fluid flow. Under the low flow conditions the collector fluid in the collectors stratified and with strong enough sun produced a steam bubble in the upper header of the collectors. A small steam bubble augmented by any trapped air would stop fluid flow, and the temperature in the collectors would then rise further.

Fig 13. Shows that a temperature of about 325 deg F the steam pressure would increase to 75 psi, enough to trip the pressure relief.

Figure 13. Steam Pressure vs Temperature

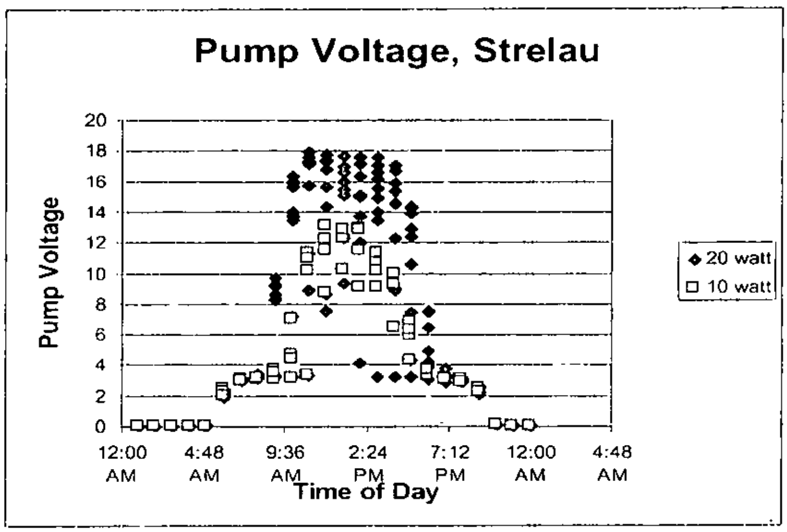


A temperature of 325 deg F is at the high margin of performance for a non flowing collector. The pump manufacturer said that common practice in Florida is to us a 125 psi pressure relief valve instead of the 75 psi version. It is marginally possible that use of the higher pressure relief valve would prevent the discharge of fluid from the solar loop.

A further remedy executed by the solar contractor was to pre-circulate the solar fluid very vigorously in-order to flush out entrapped air.

Another remedy was tested by using a 20 Watt solar panel in an effort to strengthen the early morning pump flow. Fig 14. Shows that the use of the 20 Watt PV panel did increase the pump voltage and associated flow rate.

Figure 14. Pump Voltage vs Time of Day



The use of the 20 Watt PV panels and the vigorous pre circulation are both current practice in the program and the system failures due to fluid loss have ceased.

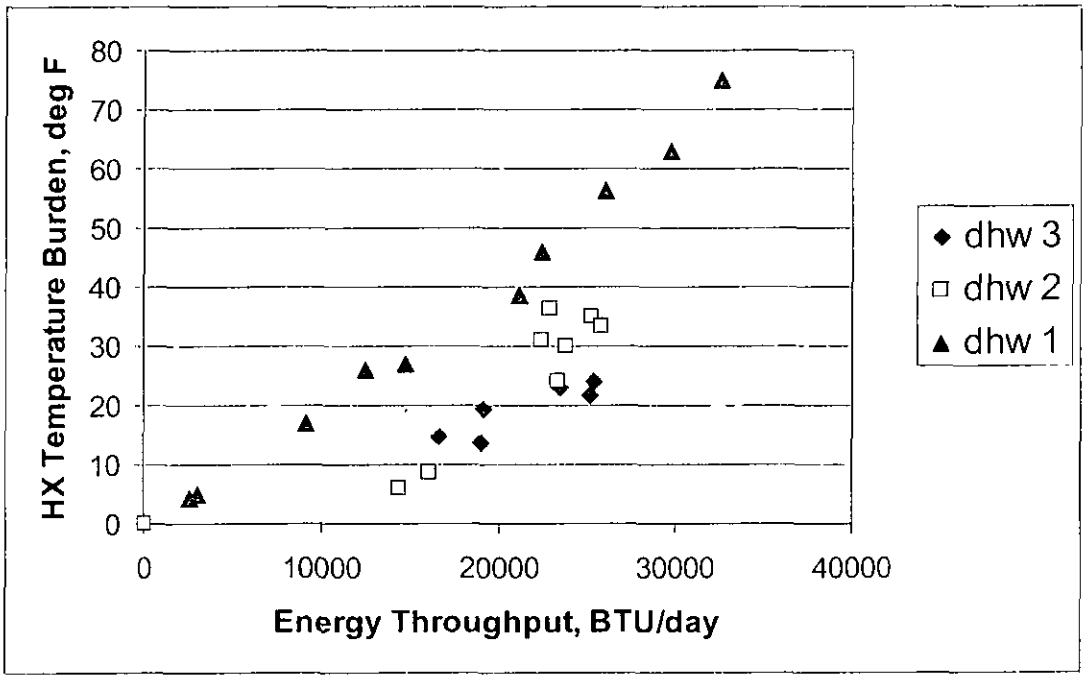
Heat Exchanger Performance

The three monitored systems employed three different types of heat exchangers as follows:

- DHW 1 a stand alone double wall heat exchanger placed next to the solar storage tank.
- DHW 2 a double wall heat exchanger formed by wrapping a copper tube around the solar storage tank and in thermal contact with the tank.
- DHW 3 a single wall heat exchanger immersed in the bottom of the solar storage tank

The system monitoring was configured to quantify the performance of the heat exchangers. Figure 15 shows a comparison of the monthly performance of the three types of heat exchangers. This comparison is based on a variable referred to here as the heat exchange burden, and expressed in deg F. Physically, this refers to the solar collector temperature increase necessary to force the collected thermal energy through the heat exchanger. A higher temperature increase corresponds to lowered system operating efficiency, hence a higher heat exchanger burden corresponds to poorer heat exchanger performance. In this comparison of heat exchanger performance, the immersed heat exchanger in DHW 3 shows the best performance. The wrap around heat exchanger in DHW 2 is slightly less effective than the heat exchanger on DHW 3. The least effective heat exchanger is the one associated with system DHW 1.

Figure 15. Comparison of Heat Exchanger Performance



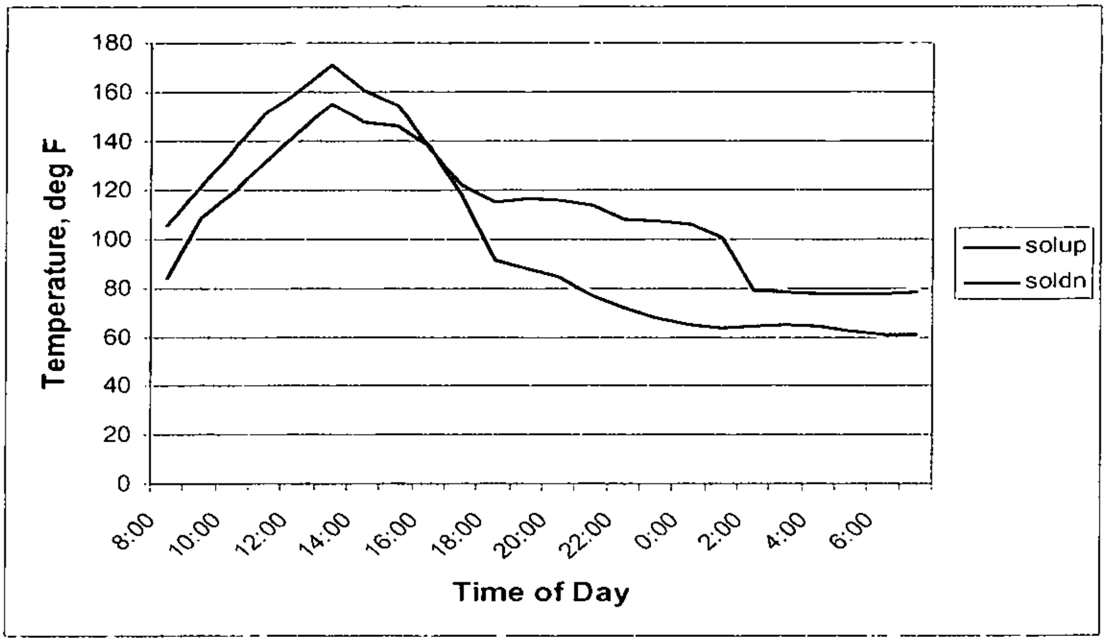
In spite of the differences in heat exchanger performance, all three types of systems performed relatively well. All three heat exchangers exhibit a heat exchange "bottleneck" which presents a design avenue for improved performance.

Convective Heat Losses

In all three of the monitored systems the solar storage tank is mounted at an elevation from 12 to 25 feet lower than the solar collectors. Whenever the tank is warmer than the solar collectors there is a natural tendency for the solar fluid warmed in the heat exchanger to rise while solar fluid cooled in the collectors simultaneously falls. If this process is unimpeded, it becomes a mechanism by which the solar storage tank can lose energy to the solar collectors overhead.

The clearest example of this heat loss mode is evident in the operation of the Oregon system, DHW 1. In this system, there is no check-valve to inhibit this heat loss mode, although there is a very long pipe run. Figure 16 shows the temperatures in the pipes going up to, solup, and the pipes returning from the solar collectors, soldn.

Figure 16. Solar Loop Temperatures DHW 1



Note in this figure that the temperatures in the solar return line, soldn, remain well above 100 deg F throughout the night. This is caused by warm solar fluid rising up convectively from the heat exchanger. The abrupt reduction in this temperature at about 1 AM was caused by several gallons of cold water flowing into the bottom of solar storage tank in the course of DHW usage at that time. This DHW draw cooled the solar storage tank and significantly reduced the convective losses. Large DHW draws at night have a tendency to diminish or stop the convective losses. The back-flow rate in the solar loop associated with this convective loss mode was not directly measured, but it must be a very low flow rate because the overall system performance was relatively good suggesting that the convective losses were not very great.

The two Philadelphia area systems DHW 2 and DHW 3 both had a check-valve to inhibit the back flow associated with the convective heat loss mode. Fig 17 and Fig 18 show the solar loop temperatures for systems DHW 2 and DHW 3. Note in Fig 17 that there appears to be a convective loss loop in system DHW 2. Even though this system has a check-valve to inhibit back flow in the solar loop, a very slow back flow appears to have developed anyway.

Figure 17. Solar Loop Temperatures DHW 2

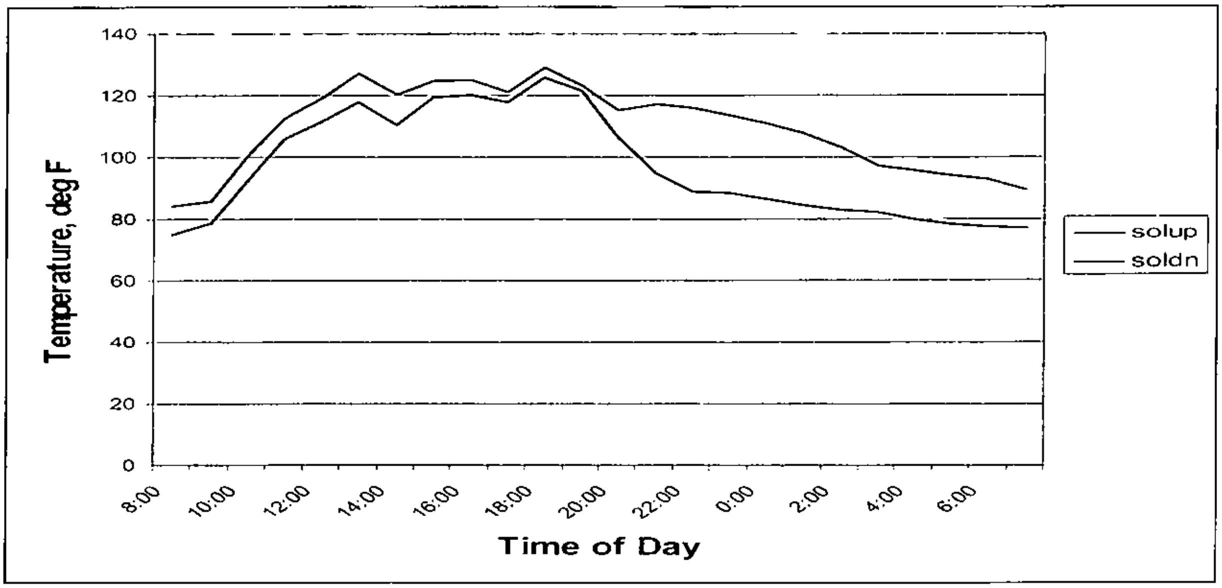


Figure 18. Solar Loop Temperatures DHW 3

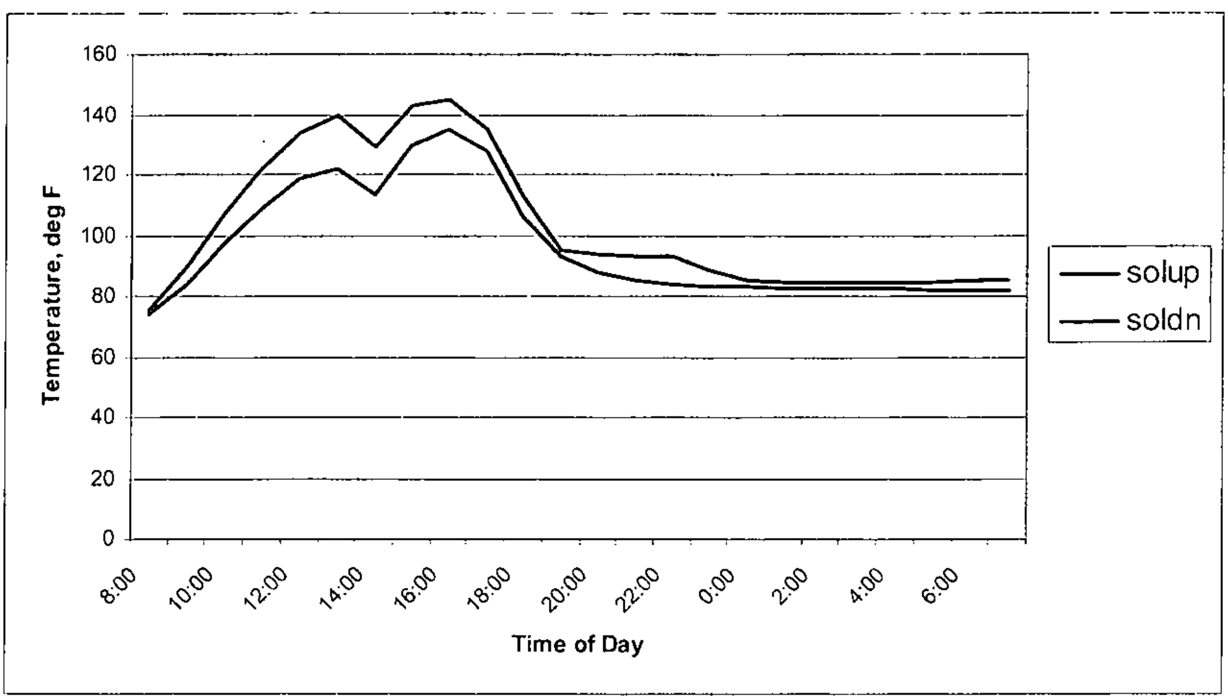


Figure 18 shows the solar loop temperatures for system DHW 3. This system is the least susceptible to the convective heat loss mode. The heat exchanger, immersed in the cold water at the bottom of the solar tank, is usually not warm enough to support the convective loss.

Appendix A. Inspection Reports

SITE INSPECTION REPORT #1

Solar DHW System

Inspection date: July 27, 1999

Installation date: Jun/Jul 1999

Location: 1331 Narragansett st, Philadelphia, PA, 19138

Name: William Purnell

SYSTEM COMPONENT DETAILS

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 29.9 ft2/panel, total 59.8 ft2 for full array

Orientation: South at 30 deg slope

Shading: none

Mounting: slope struts on a flat roof

PV array: 18 watt nominal

Relief valves: P/T on solar loop with expansion tank

Tank Assembly

Water storage: 80 gallons nominal

Insulation: R16 urethane

Pump and mounting: Hartell DCL motor as matched to 18 watt PV panel

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by antisyphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arraingement

Anode rod replacement: accessable

Piping

Solar loop piping: ¾ inch copper soldered insulated with ½ inch wall foam sleeve

Connection to Backup tank: via mixing valve to backup tank inlet

Mixer valve: located at outlet of solar tank

Insulation: 1/2 inch wall foam

UV protection: exterior rated latex paint on exposed insulation

Customer Interface

Instruction manual: none

Repair reference: sticker with installer phone # on tank

Principles of Operation: verbal explanation

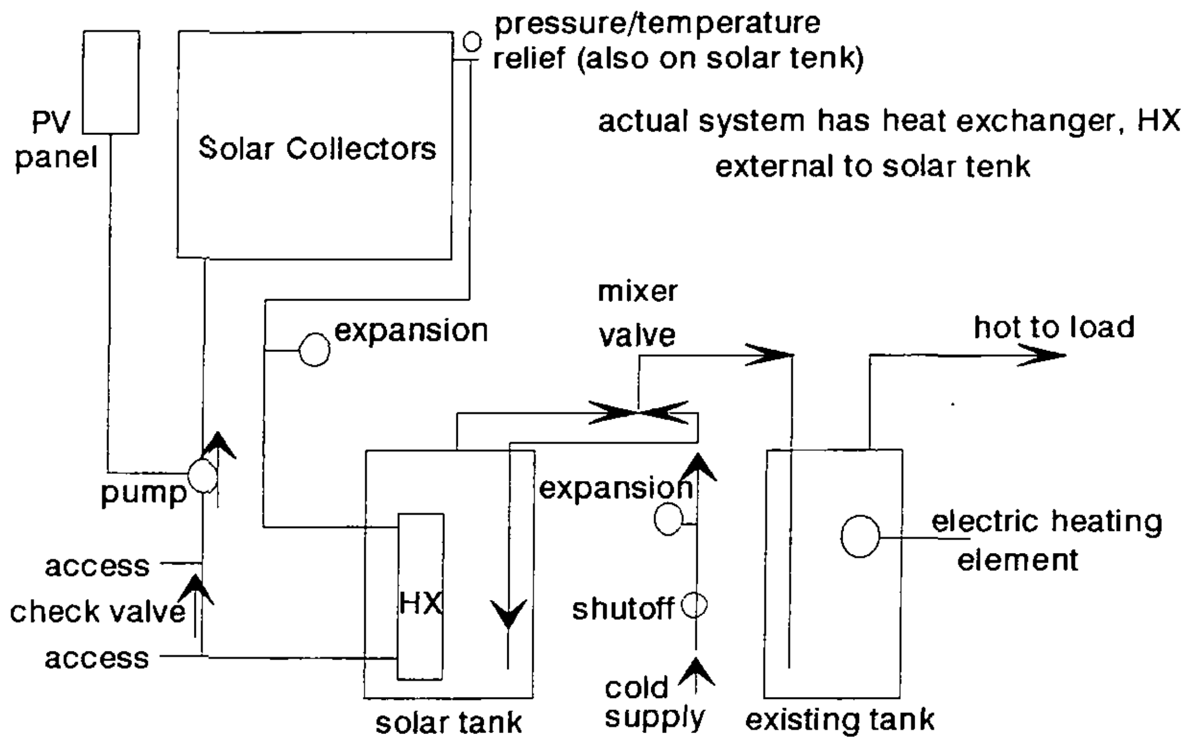


Fig 1. Solar DHW system Schematic

NOTES AND RECOMMENDATIONS:

1. In this installation, a mixer valve is plumbed between the solar tank and the backup tank. This valve is intended as a protection by providing an upper limit to the temperature of the water emerging from the solar tank. In its current position, the mixer valve will deliver the required protection, but it can also lower the operating efficiency of the whole system. More commonly the mixer valve is at the outlet from the backup tank. In this outlet position, the mixer does three important things which are not done by the mixer valve in its current position; 1) it protects against high temperature scalding arising by mis-setting the backup thermostat, 2) it increases system thermal storage by allowing stratified hot water to flow from the top of the solar tank to the base of the backup tank, and, 3) it permits early detection of mixer valve failures.

Typically a mixer valve, which is essentially a thermostat, will fail in a mode that passes only cold water. When the mixer valve is installed at the outlet of the **backup** tank, a mixer valve failure will appear is if the whole hot water system has failed, and usually prompt an immediate service call. The remedy is usually replacement of a thermostatic button readily accessible inside the mixer valve.

A benefit of the current placement of the mixer valve at the outlet of the **solar** tank is that a mixer valve failure will not be noticed as a disruption of hot water. The backup tank heating element will simply compensate for lack of hot pre-heated water from the solar tank, and the solar savings will be significantly reduced. The solar savings are reduced in this case because the failed mixer valve will not let the solar heated water out of the solar tank; the solar tank is automatically bypassed. A mixer valve in the current position will appear more reliable, but a failed valve can cripple system output in an undetectable manner.

2. The system is quite simple, but even at that, a simple system diagram and simple operating instructions should be left on site for use in an emergency shut off situation or by a future plumber or solar installer. A brief description of operation (preferrably with a colored diagram) should be left with the homeowner because they will become "de facto" solar ambassadors.

3. Pipe insulation was not in place near the tank, probably to allow for inspection and photographing of the system piping. But in typical operation, piping insulation details can account for up system performance changes of up to 10-15%. It also appears possible to have limited basksyphoning losses at night from the top of the heat exchanger by convection cells within the hot return pipe from the solar array. The system monitoring should be structured to detect night piping losses.

Inch 3

SITE INSPECTION REPORT #2

Solar Security Light System
Inspection date: July 26 1999
Installation date: July 26 1999
Location: 14 E Dogwood Court, West Ampton NJ, 08060
Name: Denise Stein

SYSTEM COMPONENT DETAILS

Overall System schematic: see figure 1.

Solar Exposure and Shading – This site has no solar shading. The PV array is mounted at the base of an East facing roof slope, with a 20 deg tilt to the South. Solar exposure on the PV array is about 80% of full exposure. This exposure may experience some shading from the roof peak in the winter afternoons.

Lighting Target Area – The security light is mounted indoors in a frequently used garage and aimed at the interior garage area.

Mounting and Durability: a new unit was screwed to an interior wall with the lead to the PV panel passing through a window crack and up to the eave where the PV pannel was propped.

Participant comments and experience: none

NOTES AND RECOMMENDATIONS –

This is an interim monitoring installation on a CMC staff residence. This is to get more subjective and operational data as a checkout before deploying this type on unit more widely.

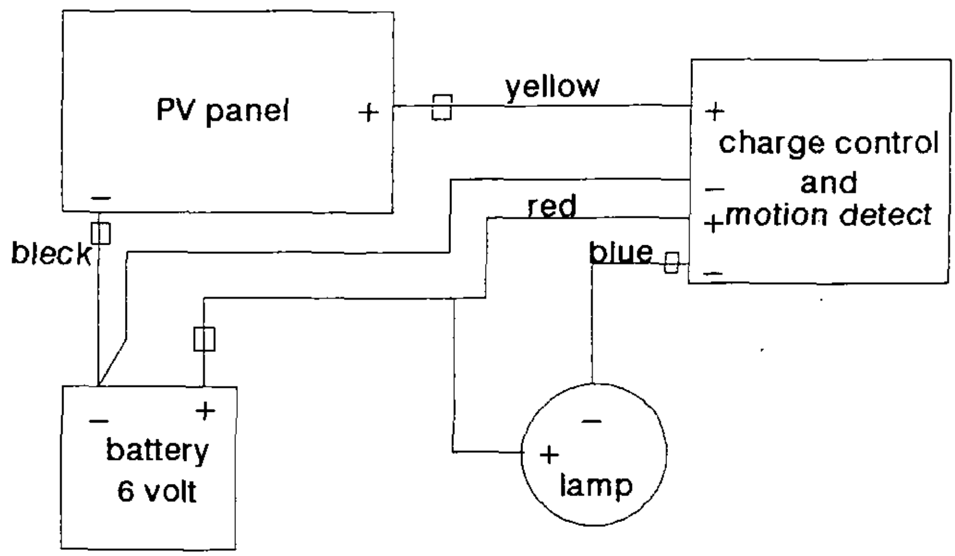


Figure 1. Solar Security Light Schematic

SITE INSPECTION REPORT #3

Solar Security Light System

Inspection date: July 26 1999

Installation date: July 26 1999

Location: 2609 Crum Creek Dr, Berwyn PA, 19312

Name: Steve Luxton

SYSTEM COMPONENT DETAILS

Overall System schematic: see figure 1.

Solar Exposure and Shading – This site has solar shading from high trees. The PV array is mounted at the base of an East facing roof slope, with a 50 deg tilt to the South. Solar exposure on the PV array is about 50% of full exposure.

Lighting Target Area – The security light is mounted outdoors and aimed at the area near the front door.

Mounting and Durability – The unit is screwed to the eave facing using a spacer shim for one corner. The PV panel is initially mounted on the unit with a SE face at 50 deg tilt. It may be moved to a south facing position on the roof ridge.

Participant experience or comments: none

NOTES AND RECOMENDATIONS -

This is an interim monitoring installation on a CMC staff residence. This is to get more subjective and operational data as a checkout before deploying this type on unit more widely.

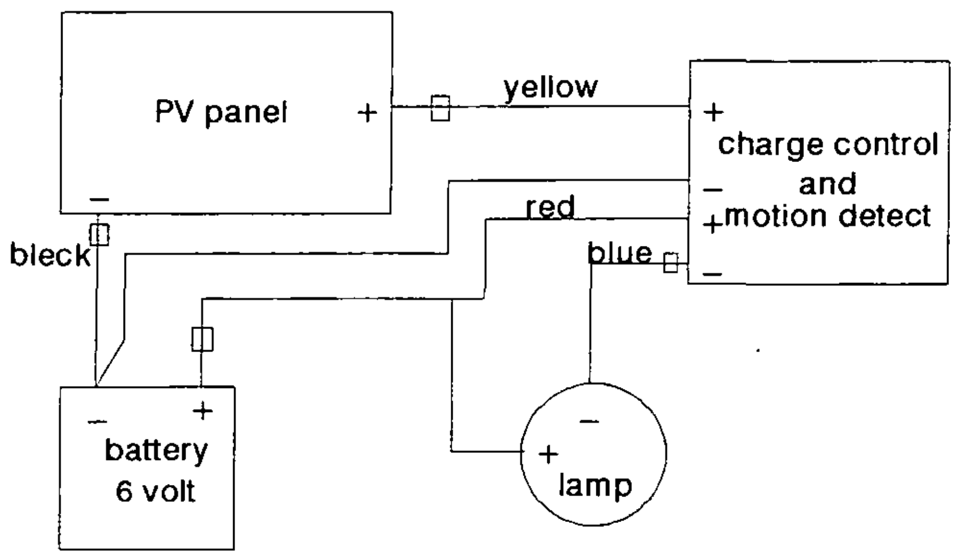


Figure 1. Solar Security Light Schematic

SITE INSPECTION REPORT #4

Solar DHW System

Inspection date: December 13, 1999
Installation date: Nov 1999
Location: 1311 Aldine st, Philadelphia, PA, 19111
Name: Ennil and Susan Pontarelli

SYSTEM COMPONENT DETAILS

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 29.9 ft2/panel, total 59.8 ft2 for full array
Orientation: South at 30 deg slope in plane of roof. Roof is second story roof.
Shading: none
Mounting: in roof plane with brackets holdin collectors approximately 4 inches off roof. Mounting brackets are bedded in silicone and lagged through roof into roof rafters.
PV array:18 watt nominal
Relief valves: Pressure relief at solar collectors. Automatic air relief at solar collector top and at about 1 foot above solar pump.

Tank Assembly

Water storage: 80 gallons nominal, with double wall heat exchange via 120 ft copper tube wrap around tank, tank insulation external to both tank and heat exchanger. Heat exchange fluid is approximately 50% solution of propelene glycol and tap water.
Insulation: R16 urethane
Pump and mounting: Hartell DCL motor as matched to 18 watt PV panel
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by antisyphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arraingement
Anode rod replacement: accessable

Piping

Solar loop piping: ¾ inch copper soldered insulated with ½ inch wall foam sleeve
Connection to Backup tank: via mixing valve to backup tank inlet
Mixer valve: located at outlet of solar tank
Insulation: 1/2 inch wall foam
UV protection: exterior rated latex paint on exposed insulation

Customer Interface

Instruction manual: none
Repair reference: sticker with installer phone # on tank
Principles of Operation: verbal explanation

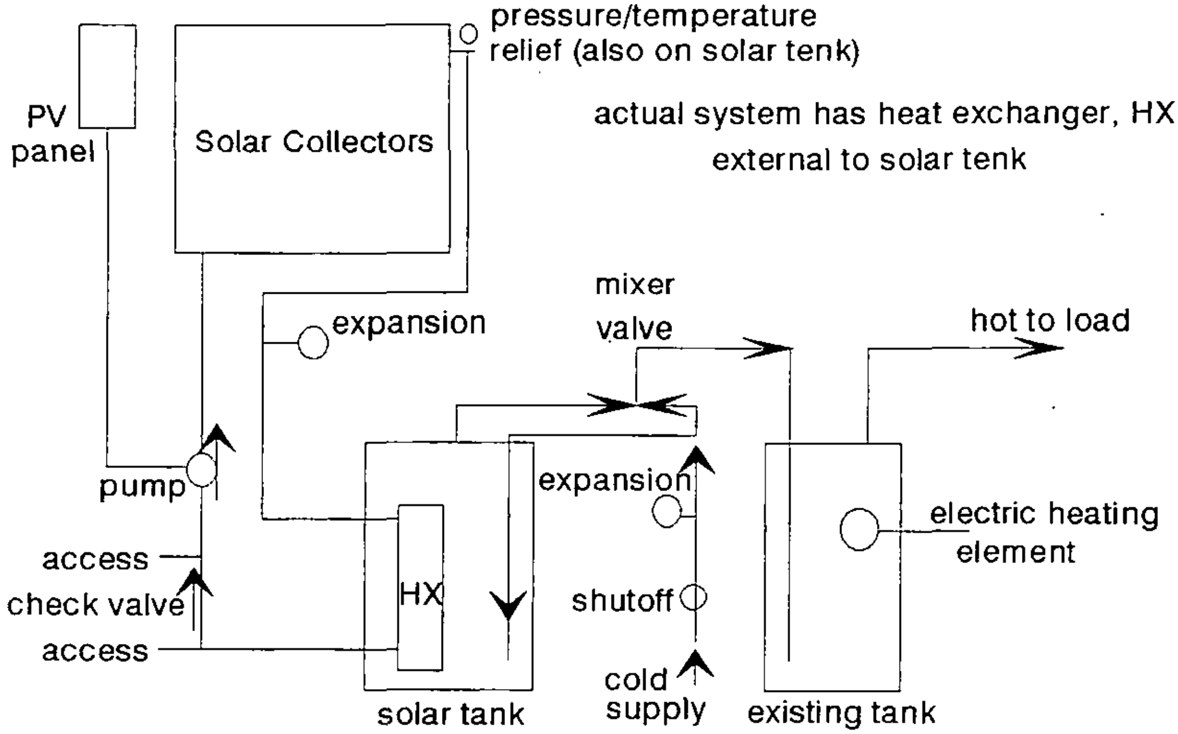


Fig 1. Solar DHW system Schematic

NOTES AND RECOMMENDATIONS:

1. In this installation, a mixer valve is plumbed between the solar tank and the backup tank. This valve is intended as a protection by providing an upper limit to the temperature of the water emerging from the solar tank. In its current position, the mixer valve will deliver the required protection, but it can also lower the operating efficiency of the whole system. More commonly the mixer valve is at the outlet from the backup tank. In this outlet position, the mixer does three important things which are not done by the mixer valve in its current position; 1) it protects against high temperature scalding arising by mis-setting the backup thermostat, 2) it increases system thermal storage by allowing stratified hot water to flow from the top of the solar tank to the base of the backup tank, and, 3) it permits early detection of mixer valve failures.

Typically a mixer valve, which is essentially a thermostat, will fail in a mode that passes only cold water. When the mixer valve is installed at the outlet of the **backup** tank, a mixer valve failure will appear is if the whole hot water system has failed, and usually prompt an immediate service call. The remedy is usually replacement of a thermostatic button readily accessible inside the mixer valve.

A benefit of the current placement of the mixer valve at the outlet of the **solar** tank is that a mixer valve failure will not be noticed as a disruption of hot water. The backup tank heating element will simply compensate for lack of hot pre-heated water from the solar tank, and the solar savings will be significantly reduced. The solar savings are reduced in this case because the failed mixer valve will not let the solar heated water out of the solar tank; the solar tank is automatically bypassed. A mixer valve in the current position will appear more reliable, but a failed valve can cripple system output in an undetectable manner.

2. The system is quite simple, but even at that, a simple system diagram and simple operating instructions should be left on site for use in an emergency shut off situation or by a future plumber or solar installer. A brief description of operation (preferrably with a colored diagram) should be left with the homeowner because they will become “de facto” solar ambassadors.

3. Pipe insulation was not in place in certain sections of the solar loop which were in-accessible This is common in solar installations.

4. Collectors have been secured to the roof by lag bolts into the roof support rafters. In this installation the mounting is secure and workmanlike. But lag screws into rafters is a practice that must be used cautiously because in cases where the rafters are also parts of roof trusses, the lag screw can weaken a key structural part of the truss. An alternative means of securing to the roof is by means of a bolt through the roof and through a 2x4 or larger spanner bridging between the undersides of two adjacent roof rafters. This alternative is referred to in the SRCC OG200 system installation specifications.

SITE INSPECTION REPORT #5
Solar DHW System
Inspection date: May 8, 2000
Installation date: April 2000
Location: 232 Washington Ave, Milmont Park, PA, 19033
Name: Robert Strehlau

SYSTEM COMPONENT DETAILS
Overall System schematic: see figure 1.

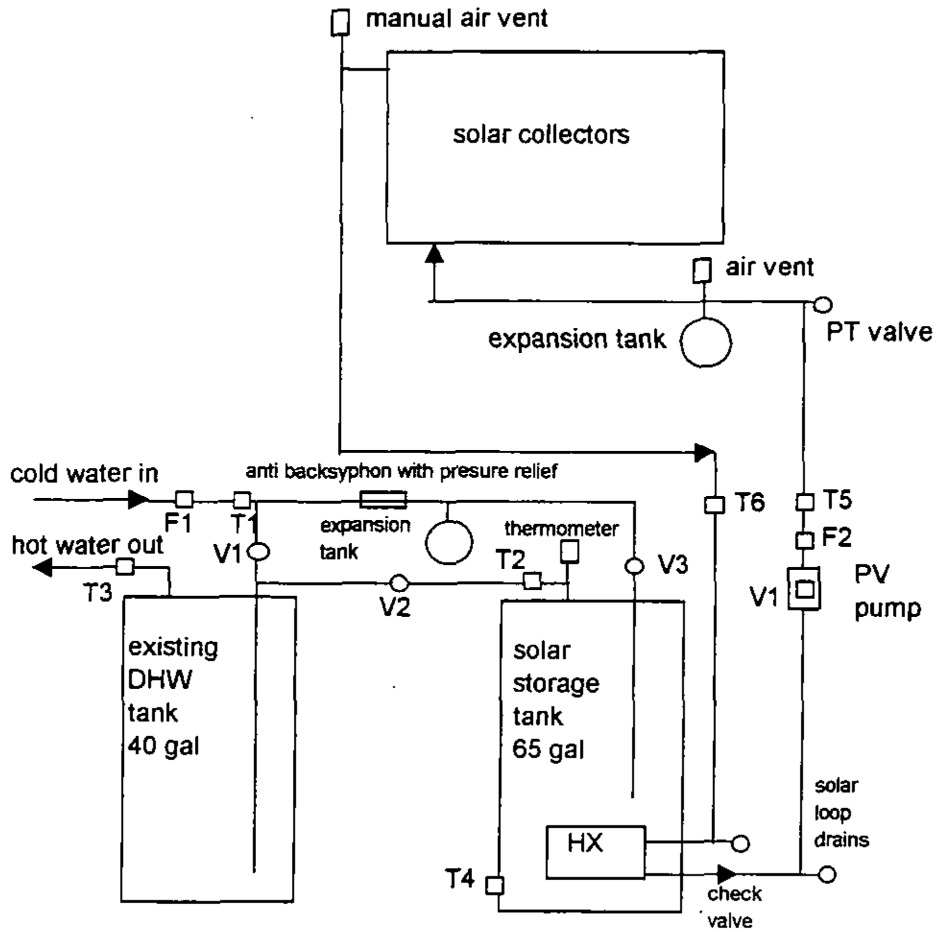
Solar collector Assembly
Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 40 deg slope on racks on flat roof. Roof is second story roof.
Shading: none
Mounting: Rack footings are bedded in silicone and lagged through roof into roof rafters.
PV array:10 watt nominal
Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and at about 1 foot above solar pump.

Tank Assembly
Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is snone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane
Pump and mounting: Ivan labsl SID10 10 watt pump with 10 watt PV panel
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by antisyphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank

Piping
Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping is shielded by metal channel.

Customer Interface
Instruction manual: none
Repair reference: call to CMC project manager.
Principles of Operation: verbal explanation

SOLAR WATER HEATING SYSTEM SCHEMATIC



Isolation Valve Settings

	solar on	solar off
V1	closed	open
V2	open	closed
V3	open	closed

Monitoring Points

T1	logged inlet temperature
T2	logged solar tank outlet temperature
T3	logged DHW outlet temperature
T4	logged tank bottom temperature
T5	logged temperature to solar collectors
T6	logged temperature from solar collectors
F1	logged DHW water flow
F2	visual solar loop flow
V1	logged PV pump voltage

NOTES AND RECOMMENDATIONS:

1. In this installation, there is no mixer valve. This is adequate for the situation because the hot solar water enters the bottom of the DHW tank and mixes by convection with the DHW water. As long as the DHW thermostat is set in the 120-130 deg F range, there will be no serious thermal transients caused by the solar system. Of course even at temperatures of 120 deg F care must be exercised by the occupants to avoid scalding by the 120 deg F hot water. This is a commonly understood precaution.

2. The system is quite simple, but even at that, a simple system diagram and simple operating instructions should be left on site for use in an emergency shut off situation or by a future plumber or solar installer. A brief description of operation (preferrably with a colored diagram) should be left with the homeowner because they will become "de facto" solar ambassadors. The home owner should clearly understand the method to isolate the solar tank in the event of a leak associated with the solar tank or in the event of future service of either tank. A system diagram with clear instructions should be left on site.

3. A reference to repair remedies (phone # of installer) should be conspicuous on the installation. The CMC project manager should be an advisory part of the loop only. The warranty remedies should be part of the installation contractors scope of work.

4. The inspection was at midday on a very hot and sunny day. The inspection showed a very hot 200 deg solar return line. At the same time the tank was only about 90 deg F and the pressure was 40 psi. These observations suggest a very slow pumping rate. The pump voltage was 10 volts indicating the pump was at full power. The flow meter on the solar line showed about .25 gpm. After disconnecting and reconnecting the pump, the pressure changed to about 35 psi, the flow increased to .6 gpm, and the solar return line cooled so that the solar delta t was 25 deg F. This is anomalous operation either caused by poor electrical connections for the pump or by a steam lock at the collectors. This was an extremely hot day and this type of operation may test the operating limits of the system.

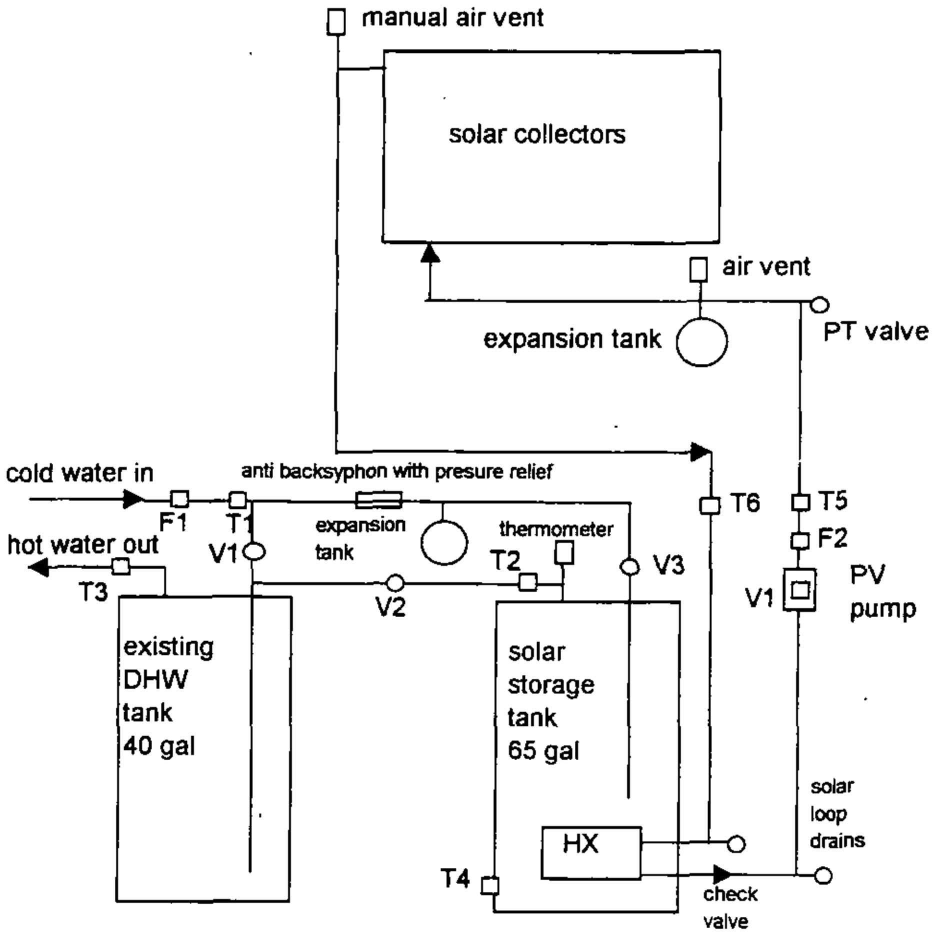
5. The pipe hanger at the top of the line from the PV pump up to the collectors was somewhat loose allowing the heavy air relief valve and expansion tank too much play which could stress the flow meter in the line.

SITE INSPECTION REPORT #6
Solar DHW System
Inspection date: May 8, 2000
Installation date: April 2000
Location: 1446 Talleyn Av, Linwood, PA, 19061
Name: Donald Cacciatore
Contractor: Davis, Modern Heating and Cooling
SYSTEM COMPONENT DETAILS -
Overall System schematic: see figure 1.

Solar collector Assembly
Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 40 deg slope on racks on west sloping roof. Roof is second story roof.
Shading: none
Mounting: Rack footings are bedded in silicone and lagged through roof into roof rafters.
PV array: 10 watt nominal
Relief valves: Pressure relief at solar tank. Manual air relief at each (2) solar collector top and at about 1 foot above solar pump.
Tank Assembly
Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane
Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank
Piping
Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface
Instruction manual: none
Repair reference: call to CMC project manager.
Principles of Operation: verbal explanation

SOLAR WATER HEATING SYSTEM SCHEMATIC



Isolation Valve Settings

	solar on	solar off
V1	closed	open
V2	open	closed
V3	open	closed

Monitoring Points

T1	logged inlet temperature
T2	logged solar tank outlet temperature
T3	logged DHW outlet temperature
T4	logged tank bottom temperature
T5	logged temperature to solar collectors
T6	logged temperature from solar collectors
F1	logged DHW water flow
F2	visual solar loop flow
V1	logged PV pump voltage

NOTES AND RECOMMENDATIONS:

1. In this installation, there is no mixer valve. This is adequate for the situation because the hot solar water enters the bottom of the DHW tank and mixes by convection with the DHW water. As long as the DHW thermostat is set in the 120-130 deg F range, there will be no serious thermal transients caused by the solar system. Of course even at temperatures of 120 deg F care must be exercised by the occupants to avoid scalding by the 120 deg F hot water. This is a commonly understood precaution.

2. The system is quite simple, but even at that, a simple system diagram and simple operating instructions should be left on site for use in an emergency shut off situation or by a future plumber or solar installer. A brief description of operation (preferably with a colored diagram) should be left with the homeowner because they will become "de facto" solar ambassadors. The home owner should clearly understand the method to isolate the solar tank in the event of a leak associated with the solar tank or in the event of future service of either tank. A system diagram with clear instructions should be left on site.

3. A reference to repair remedies (phone # of installer) should be conspicuous on the installation. The CMC project manager should be an advisory part of the loop only. The warranty remedies should be part of the installation contractors scope of work.

4. The collectors have been mounted on the west sloping roof on racks so that they face south with approximately a 40 deg slope. This gives the collectors an almost ideal orientation for maximum solar gain, but it also leaves the collectors quite visually conspicuous and at a compound angle which does not blend well with the roof. The collectors are also mounted in a step fashion which. complicates the flow path and increases the potential for air locks in the system. This is why there is an air relief on each collector instead of one air relief for the whole array. The optimum collector orientation has been studied in detail with a consensus rule of thumb being that a south orientation and a slope equal to the latitude+10 deg would have the best solar gain. But the same studies also showed that wide variations from this ideal would lead to solar gains within +- 15% of the maximum. Current solar siting practice favors a small sacrifice in solar gain in exchange for esthetics. A good rule of thumb to use is to site collectors flat on a sloping roof whenever the roof slopes at south +-45 degrees azimuth. In this case the roof was facing due west and did not even fit this rule. In this case the collectors should have been slightly oversized to 4x8 collectors instead of the current 4x6 collectors to compensate for the less than ideal orientation. The oversized 4x8 collectors on the west roof slope would have greater solar gain than the 4x6 collectors on the optimum slope. The increased cost of the oversized collectors would be almost compensated by the reduced cost of the racking.

5. Where the piping to and from the collector array traverses a sloping roof, some consideration should be given to the effect on the piping by moving snow on the roof. The basic strategy employed in this installation of running the piping up the outside wall then across the roof is a good way to keep piping costs low, and it is probably necessary to avoid the complexity of running the piping inside the building. But this strategy involves running the piping across the roof slope exposing the piping to stress caused by moving snow. The point where the piping goes over the roof eave should be well secured.

6. At this inspection, on a very sunny afternoon, the pump was running but there was no fluid circulation. Both solar lines were at room temperature indicating no circulation. The pump voltage was measured at 10 volts and the pump current was .5 amps indicating a pump power of 5 watts approximately right for 4 PM. There also appeared to be no gain in the solar storage tank. The solar loop pressure was 30 psi. These observations suggest an air or steam lock at the collectors. The contractor was notified and a reinspection in two days was performed. The contractor did find an air lock at the collectors and manually bled the air of the system. A reinspection the next day showed a properly operating system.

7. There was no pipe hanger at the top of the line up from the solar pump. This forces that line to support the weight of the heavy air relief valve and expansion tank. There should be a pipe hanger here to relieve stress on this line.

SITE INSPECTION REPORT #7

Solar DHW System

Inspection date: June 28, 2000, approximately 12 noon hazey sun

Installation date: April 2000

Location: 700 Logan St Pottstown, PA, 19464

Name: David Yednock 610 970 1297

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – full system inspection

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 30 deg slope mounted directly to roof. Roof is second story roof.

Shading: none

Mounting: collector support brackets 2 at top and bottom of collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter store on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #8

Solar DHW System

Inspection date: June 28, 2000, approximately 1PM hazey sun
Installation date: June 28 2000
Location: 432 Cherry St, Pottstown, PA, 19464
Name: Allen Shultz 610 326 3664
Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – observed installation and system charging in progress

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 40 deg slope rack mounted on flat portion of roof. Roof is second story roof.
Shading: none
Mounting: rack support frames bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5
PV array: thin film BP 10 watt nominal mounted on west side of collectors no serious shading by side of collector.
Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.
Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual
Repair reference: call to CMC project manager.

SITE INSPECTION REPORT #9

Solar DHW System

Inspection date: June 28, 2000, approximately 2 PM hazey sun
Installation date: June 28 2000
Location: 1139 South St, Pottstown, PA, 19464
Name: Audra Boyer 610 326 7117
Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – exterior inspaction only urban townhouse accessable only with scaffolding

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 30 deg slope directly mounted on roof. Roof is second story roof.
Shading: none
Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5
PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.
Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.
Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual
Repair reference: call to CMC project manager.
Principles of Operation: verbal explanation

SITE INSPECTION REPORT #10

Solar DHW System

Inspection date: June 28, 2000, approximately 3 PM hazey sun

Installation date: June 28 2000

Location: 2573 Terrace Hill Ct, Pottstown, PA, 19464

Name: Katherine Scott 610 718 9025

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – full inspection , complex pipe run on modern appartment

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 30 deg slope directly mounted on roof. Roof is second story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: *call to CMC project manager.*

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #11

Solar DHW System

Inspection date: June 29, 2000, approximately 12 PM dull hazey sun

Installation date: June 28 2000

Location: 124 President Ave, Rutledge, PA, 19070

Name: Robert Ashleigh 610 544 2542

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – full inspection system on attractive victorian house

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 30 deg slope rack mounted on roof. Roof is third story roof.

Shading: large deciduous tree shades morning sun in winter half of year til about 10:00

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #12

Solar DHW System

Inspection date: June 29, 2000, approximately 2 PM dull hazey sun

Installation date: June 28 2000

Location: 1029 Yeadon Ave, Yeadon, PA, 19050

Name: Willie Robinson 610 259 8128

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS - full site inspection

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #13

Solar DHW System

Inspection date: Aug 13, 2000,

Installation date: June 28 2000

Location: 105 Wynnewood Dr, Coatsville, PA, 19320

Name: Rhonda Dever 610 466 9083

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – full site inspection needs more pipe support at tank

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #14

Solar DHW System

Inspection date: Aug 13, 2000,

Installation date: June 28 2000

Location: 1831 W Kings Hwy, Coatsville, PA, 19320

Name: Michael Proudfoot 610 857 9101

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – reported pressure irregularity traced to well pump control

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #15

Solar DHW System

Inspection date: Aug 13, 2000,
Installation date: June 28 2000
Location: 874 Coats St, Coatsville, PA, 19320
Name: Shaheena Mcgibboney 610 384 7138
Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – system inoperable

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.
Shading: none
Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5
PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.
Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.
Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual
Repair reference: call to CMC project manager.
Principles of Operation: verbal explanation

SITE INSPECTION REPORT #16

Solar DHW System

Inspection date: Aug 13, 2000,

Installation date: June 28 2000

Location: 120 S 3rd Ave, Coatsville, PA, 19320

Name: Gloria Love 610 380 4605

Contractor: Davis, Modern Heating and Cooling

SYSTEM COMPONENT DETAILS – collectors racked on north roof observed externally

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #17

Solar DHW System

Inspection date: Aug 13, 2000,

Installation date: June 28 2000

Location: 1047 Forgemans Rd, Coatsville, PA, 19320

Name: Dennis Dantzler 610 380 8432

Contractor: **Davis, Modern Heating and Cooling**

SYSTEM COMPONENT DETAILS -

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #18

Solar DHW System

Inspection date: Aug 13, 2000,

Installation date: June 28 2000

Location: 40 Lafayette Ave, Coatsville, PA, 19320

Name: Arron Pinkney 610 380 86278Contractor: **Davis, Modern Heating and Cooling**

SYSTEM COMPONENT DETAILS – Observed externally mounted on ranch style

Overall System schematic: see figure 1.

Solar collector Assembly

Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface

Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.

Shading: none

Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5

PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.

Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.

Tank Assembly

Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propylene glycol and tap water.

Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.

Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections

Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly

Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank

Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement

Anode rod replacement: no anode in solar storage tank

Piping

Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.

Connection to Backup tank: output of solar tank direct to input of DHW tank.

Mixer valve: none

Insulation: 1/2 inch wall foam

UV protection: exterior piping with insulation is shielded by vynil channel.

Customer Interface

Instruction manual: system ID tag but no manual

Repair reference: call to CMC project manager.

Principles of Operation: verbal explanation

SITE INSPECTION REPORT #19
Solar DHW System
Inspection date: Aug 13, 2000,
Installation date: June 28 2000
Location: 80 Cohen St, Coatsville, PA, 19320
Name: Donald Forte 610 380 8432
Contractor: **Davis, Modern Heating and Cooling**
SYSTEM COMPONENT DETAILS racked panels system viewed from exterior
Overall System schematic: see figure 1.
Solar collector Assembly
Net Area: 23.09 ft2/panel, total 46.18 ft2 for full array, selective surface
Orientation: South at 40 deg slope rack mounted on roof. Roof is third story roof.
Shading: none
Mounting: collector support backets 2@ top and bottom of each collector bedded in silicone and lagged through roof into roof rafters. Lag bolts used are 3/8 x 5
PV array: thin film BP 10 watt nominal mounted on west side of collectors, no serious shading by side of collector.
Relief valves: Pressure relief at solar tank. Manual air relief at solar collector top and automatic air relief about 2 feet above solar pump.
Tank Assembly
Water storage: 65 gallons nominal, with removable single wall heat exchange with 20 ft copper tube with external fins inside tank. Tank interior is stone lined to prevent corrosion. Heat exchange fluid is approximately 65% solution of propelene glycol and tap water.
Insulation: R16 urethane shielded by white vynil gutter storc on vertical and by 2 ½ inch black ribbed drain pipe on roof exposure all secured by pipe clamps.
Pump and mounting: Ivan labs SID10 10 watt pump with 10 watt PV panel with soldered connections
Anti-thermosyphoning: gravity check valve at bottom of heat exchanger no check at top of heat exchanger or in the pump assembly
Relief valves: expansion tank on full DHW system necessitated by anti-syphon valve, P/T on both solar tank and backup tank
Access: fill/drain access, two ports at base of HX, a convenient fill charge arrangement
Anode rod replacement: no anode in solar storage tank
Piping
Solar loop piping: 5/8 inch soft copper refrigeration tube soldered and insulated with ½ inch wall foam sleeve. Piping is external to house above basement.
Connection to Backup tank: output of solar tank direct to input of DHW tank.
Mixer valve: none
Insulation: 1/2 inch wall foam
UV protection: exterior piping with insulation is shielded by vynil channel.
Customer Interface
Instruction manual: system ID tag but no manual
Repair reference: call to CMC project manager.
Principles of Operation: verbal explanation

Appendix B. Monitoring Preparation and Installation Documents

MONITORING PREPARATION
and
BENCH TESTING REPORT

Prepared for
PECO Energy – Universal Service
Valeria Bullock, manager
July 29, 1999

By
Howard Reichmuth P.E.
HGP and Associates/Stellar Processes Inc
607 Hazel St
Hood River, Oregon 97031
541-490-3175

SUMMARY – This monitoring is undertaken as part of the impact evaluation for the PECO Energy Renewables Pilot Program. Two solar applications, a solar water heating system and a solar security light intended for use in the PECO low income renewables program have both been examined. Based on this preliminary examination, detailed plans for monitoring this equipment have been prepared and are presented as parts 1 and 2 of this report. Overall the monitoring plans call for monitoring at four separate sites, two sites for each type of solar application.

The monitoring equipment necessary to execute the monitoring plans has been purchased and mocked up (bench tested) to test the desired measurements. The monitoring plans have been derived based on some preliminary measurements and a site inspection which are separately documented as : monitoring report #1, and site inspection report#1.

PART 1. - Monitoring Plan for Solar Water Heating Installations

BACKGROUND

This monitoring is undertaken as part of a pilot program sponsored by PECO Energy of Philadelphia Pa and executed by CMC Energy Services. This program is intended to serve low income customers of PECO by using solar hot water heating (solar DHW) to lower hot water heating costs.

The intended installation sites are predominantly urban, typically two story row houses. The clients are primarily motivated by the energy cost savings afforded by the solar DHW and possibly by general ecological concerns; they are not drawn to this option out of particular interest in the technology. Therefore, the installations must have a high level of reliability, comparable to or exceeding that to be expected from a typical household appliance.

The principal candidate system uses two 64 ft2 collectors, an 80 gallon storage tank, and a photo-voltaic powered pump as illustrated in fig 1. Note that the system has no controller per se; the PV panel is connected directly to a DC pump: "The pump pumps when the sun shines".

Two of the systems to be installed during summer 1999 are to be instrumented and monitored for approximately one year to establish an engineering basis for performance estimates, to verify details of operation by providing an initial system commissioning, and to assist in the refinement of the system if necessary. The use of two monitoring installations greatly increases the viability of the monitoring project by providing the measurement redundancy necessary to obtaining long term performance data. An inspection of the first system installed (see inspection report #1) showed that systems deployed in this context will typically have a two and ½ story vertical pipe run from the basement tank location to the roof top collectors.

This long vertical pipe run may be the defining challenge in the installation and operating performance of the system. Simplification of the installation may require that the pipe run be external to the building, and a long pipe run of this type may have significant heat losses both during circulation and via back syphoning at night.

The monitoring subject is a system with an emphasis on simplicity and reliability. The inefficiencies incurred by this system are intended to be overcome by the generous size of the collector array, 64ft2.

MONITORING OBJECTIVES

The principal monitoring objectives are to verify system reliability and to quantify the solar contribution provided by the system. A secondary monitoring objective is to explore the details of the system operation for potential system improvements.

Specifically, the monitoring is intended to quantify the following:

a) the overall hot water heating load
b) the portion of the load displaced by solar heat
c) system loss components: standby loss, circulation loss, back syphon loss
d) system operating pattern, pump times and flows
e) system heat transfer impacts.

The monitored data is intended to be complete enough to describe a daily energy balance of the DHW system.

MONITORING METHODOLOGY

This measurement exercise will employ three primary streams of information. 1) The bulk of the monitoring will be done by a data logger, collecting of the order of 10 measurements every hour for the entire one year duration of the monitoring exercise. 2) The data logged information will be augmented by one time site measurements, which are used as calibrations necessary to interpret the data logged information. 3) Finally, auxilliary experimental measurements of materials properties may be made as necessary in-order to enhance the utility of the monitored information. Each of these data streams is discussed below:

MONITORED MEASUREMENTS

Monitoring measurements will be made by a Lambert DataTrap on an hourly basis for the entire monitoring period. The hourly measurements will be retrieved by phone line connection approximately every two weeks and compiled into a monthly monitoring status report. It is important to access the data frequently in-order maintain current status of the solar DHW system and the data logging system.

The following measurements will be made on an hourly basis by the data logger:

1. The DHW flow at the inlet to the solar tank
2. The DHW inlet water temperature upstream from the inlet to the solar tank
3. The DHW outlet temperature at the hot outlet of the auxiliary tank
4. Flow temperature to the solar collectors several feet above the pump
5. Flow temperature from the solar collectors several feet above the solar tank
6. Ambient temperature at the tank
7. DC voltage at the solar pump
8. Element power (220V) at the auxiliary tank
9. Solar tank outlet temperature
10. Outdoor air temperature
11. Solar insolation in the plane of the collectors
12. Cumulative BTU, meas#1*(meas#3-meas#2)
13. Minimum inlet temperature, the minimum value of measurement #1

With reference to the solar DHW system, the data logger measurements are made approximately at the locations noted in figure 2.

ONE TIME SITE CALIBRATION MEASUREMENTS

The site calibration measurements are made during the installation of the monitoring hardware and are used to refine the accuracy of the monitored data. Three site calibration measurements will be made:

1. Inlet water temperature correction – water will be run through the DHW system for several minutes and the temperature a cold water stream will be measured directly and compared to the cold inlet temperatures measurements, measurements#2&9. If necessary a correction for meas#9 will be developed using the tank ambient temperature, meas#8 and the inlet temperature, meas#2. This type of correction is commonly necessary because the inlet temperature measurement will initially be close to the tank ambient temperature and it will typically require a finite time perhaps of the order of minutes to register the proper inlet temperature. The temperature sensors for meas#3, meas#4, meas#5, and meas#6 will all calibrated to match meas#2 at room temperature.
2. Pump flow calibration – Solar loop flow will be read from a manually observed flow meter, as well as the corresponding pump voltage. Flow and voltage will be observed at 4 levels of solar intensity or flow. These observations will be fitted to a function for pump flow vs observed pump voltage.
3. If the pump resistance is low enough, of the order of 3-6 ohms, then the observed pump voltage could be correlated to simultaneously measured solar insolation in the collector plane. This type of measurement is conspicuously dependent on the operating temperature of the PV panel. A temperature correction would be derived based on the pump IV curve and the temperature dependent IV curves for the PV panel.
4. The pump IV curve, voltage and current at several different voltages between 9 and 15 volts, would be measured using a DC voltage source. This measurement should be done with the solar loop filled and the pump connected to the voltage source. This measurement is done with #2 above.

AUXILIARY EXPERIMENTAL MEASUREMENTS

Auxiliary experimental observations, such as thermal loss from pipes or valve assemblies may be made if necessary to interpret the monitoring observations.

PART 2. - Monitoring Plan for Solar Security Lighting Installations

BACKGROUND

This monitoring is undertaken as part of a pilot program sponsored by PECO Energy of Philadelphia Pa and executed by CMC Energy Services. This program is intended to serve low income customers of PECO by using solar security lighting to lower electricity costs.

The subject installation sites are predominantly urban, typically two story row houses. The clients are primarily motivated by the energy cost savings afforded by the solar security lighting, and possibly by general ecological concerns; they are not drawn to this option out of particular interest in the technology. Therefore, the installations must have a high level of reliability, comparable to or exceeding that to be expected from a typical household appliance.

The principal candidate system uses a small solar PV panel, a 6 amp-hour sealed lead acid battery and a 5 watt halide light on an occupancy sensor control as is illustrated in fig 3. The system schematic in fig 3 also notes the monitoring points for this system.

Two of the systems to be installed during summer 1999 are to be instrumented and monitored for approximately one year to establish an engineering basis for performance estimates, to verify details of operation by providing an initial system commissioning, and to assist in the refinement of the system if necessary. The use of two monitoring installations greatly increases the viability of the monitoring project by providing the measurement redundancy necessary to obtaining long term performance data.

A preliminary operational test of two systems (see monitoring report #1) showed that systems deployed in this context may experience periods of system shut down when battery drain exceeds battery input for an extended period. Also there may be circumstances which lead to extensive "false triggering" of the security light.

The suitability of this device for security purposes apparently depends on the proper balance of lighting use with solar electric gain. Both the battery element and the solar PV element have performance which varies seasonally or with temperature.

MONITORING OBJECTIVES

The principal monitoring objectives are to verify system reliability and to quantify the solar contribution provided by the system. A secondary monitoring objective is to explore the details of the system operation for potential system improvements.

Specifically, the monitoring is intended to quantify the following:

- overall system lighting operation, lighting energy from battery
- battery voltage and temperature
- PV voltage and current, PV energy to battery
- system operating pattern
- battery charging circuit operation

The monitored data is intended to be complete enough to describe a daily energy balance for the solar security light system.

MONITORING METHODOLOGY

This measurement exercise will employ three primary streams of information. 1) The bulk of the monitoring will be done by a data logger, collecting of the order of 10 measurements every hour for the entire one year duration of the monitoring exercise. 2) The data logged information will be augmented by one time site measurements, which are used as calibrations necessary to interpret the data logged information. 3) Finally, auxilliary experimental measurements of materials properties may be made as necessary in-order to enhance the utility of the monitored information. Each of these data streams is discussed below:

MONITORED MEASUREMENTS

Monitoring measurements will be made by a Lambert DataTrap on an hourly basis for the entire monitoring period. The hourly measurements will be retrieved by phone line connection approximately every two weeks and compiled into a monthly monitoring status report. It is important to access the data frequently in-order maintain current status of the solar security lighting system and the data logging system.

The following measurements will be made on an hourly basis by the data logger:

1 - The PV panel voltage relative to battery ground
2 - The battery voltage relative to battery ground
3 - The PV array current
4 - The battery temperature
5 - The lighting ON status
6 - The number of light on events in the hour

With reference to the solar security lighting system, the numbered data logger measurements are made approximately at the locations noted in figure 3. This monitoring requires attachment of sensors at several points within the security light assembly. The best approach is to wire the loggers to the security light in a laboratory setting, and to pretest the completed assembly before installation in the field.

ONE TIME SITE CALIBRATION MEASUREMENTS

The site calibration measurements are made during the installation of the monitoring hardware and are used to refine the accuracy of the monitored data. Only one site calibration measurement will be made: Lighting power calibration – the security light will be triggered on with the associated current and voltage measured. A function of lighting power vs battery voltage will be derived.

AUXILIARY EXPERIMENTAL MEASUREMENTS

Auxiliary experimental observations are not planned for this type of monitoring subject.

MONITORING INSTALLATION DOCUMENTATION

MONITORING SYSTEM IDENTIFICATION

System Type: Solar Security Light – Solar Centurion
Installation Report #: 1
Installation Date: July 26, 1999
Installation designation : Solar 1
Location: 14 E Dogwood Court, West Ampton NJ, 08060
Name: Denise Stein
Phone #: data 609 267 8694 talk 609 267 4507
Communication Settings: 1200 baud,n,8,1 ASCII format
Data Logger Serial #: DT002070
Data Template file: SOL10.wk3

MONITORING SYSTEM INSTALLATION NOTES

System Configuration and Monitoring Points – The monitored system configuration and the monitoring points are shown in figure 1.

Data Logger Channel Table – *The data logger channel assignments and calibrations are* given in the channel table attached as Table 1.

Solar Exposure and Shading – This site has no solar shading. The PV array is mounted at the base of an East facing roof slope, with a 20 deg tilt to the South.

Lighting Target Area – The security light is aimed at the interior of a garage used frequently for entrance and egress. There is some question as to weather the existing garage lighting will trigger the security light.

Site Measurement, Light Power – Light power measured as 6.35 V at .903 amps. Light power estimated as, watts = 5.73. Bulb resistance, R, is 7.03 ohms. Formula for power as a function of battery voltage is watts = v^2/R.

DEFINITION OF DATA TEMPLATE VARIABLES

Battery Temperature – Mean hourly battery temperature inside the battery box, deg F.
Batt on Battery voltage graph – Mean hourly battery voltage, V. In the range of 6-7 volts.
PV-Batt on Battery Voltage graph – Mean hourly difference between PV voltage and Battery voltage. An hourly graph of this variable shows the activity of the charge control.
Lighting cycles/hr on the Battery voltage graph – Number of times the light is triggered on in the hour
Solar Gain on Energy Input Output graph – Hourly energy output from the PV array into the battery in milliwatthours.
Lighting energy on Energy input/output graph – Hourly energy into the light in milliwatt hours

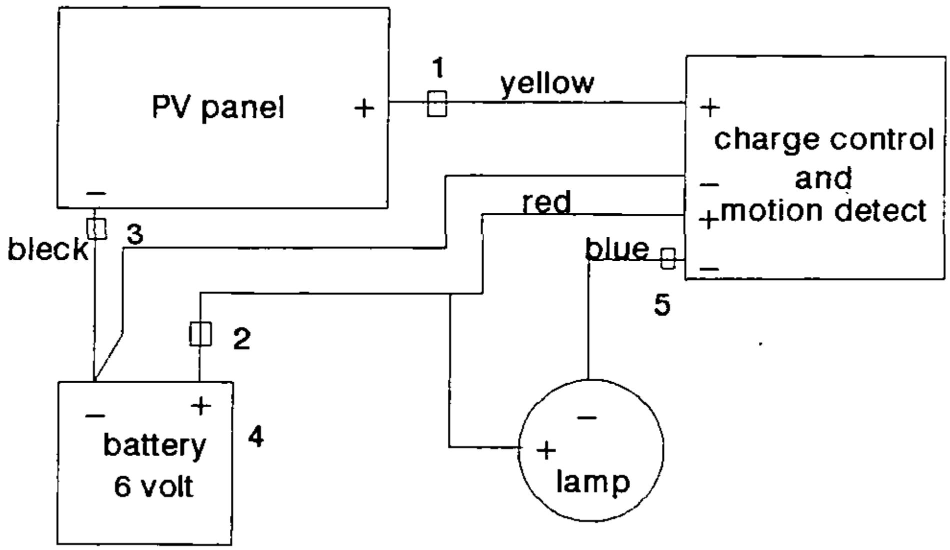


Figure 1. Solar Security Light Schematic

Monitoring Points

1 PV array voltage relative to − battery
2 Battery voltage relative to − battery
3 PV array current, via V on shunt resistor
4 Battery temperature
5 Lamp on/off status, if V<1 lamp on

TABLE 1. DATA LOGGER SET UP PARAMETERS

CURRENT SYSTEM CONFIGURATION

Channels Active:	7	Auto-Dial:	DISABLED
Channels Stored:	7	Day:	
Storage Interval:	60 MINUTES	Time:	
Free Data Storage:	798.5 DAYS	Auto-Answer:	1 RING(S)
Total Data Storage:	914.2 DAYS	Day:	EVERYDAY
Oldest Stored Data:	05/19 09:00	Starting:	00:00
Last Data Download:	07/22 10:00	Ending:	24:00
Baud Rate:	1200 BPS		

Current Time: THURSDAY 07/22/99 19:12:51

Site ID#: SOLAR 1 Unit Serial No.: DT002013

OUTPUT MENU CHOICES STILL ACTIVE

#	NAME	UNITS	TYPE	SLOPE	INCPT	'A'	'B'	'C'	'D'	'E'
9	PV Volts	Volts	3	10.16	0.00	0	0	0	0.00	0.00
10	PV mAmps	milliAmp	4	-8900.00	-9.00	0	0	0	0.00	0.00
11	BattVolt	Volts	3	10.16	0.00	0	0	0	0.00	0.00
12	Lamp-	Volts	3	10.17	0.00	0	0	0	0.00	0.00
13	BatTemp	Deg.F.	1	1.00	0.00	0	0	0	0.00	0.00
41	Lamp	Status	20	1.00	0.00	0	0	12	0.25	1.30
42	Lamp	Cycles	21	1.00	0.00	41	1	0	0.00	0.00

OUTPUT MENU CHOICES STILL ACTIVE

MONITORING INSTALLATION DOCUMENTATION

MONITORING SYSTEM IDENTIFICATION

System Type: Solar Security Light – Solar Centurion
Installation Report #: 2
Installation Date: July 26, 1999
Installation designation : Solar 2
Location: 2609 Crum Creek Dr, Berwyn PA, 19312
Name: Steve Luxton
Phone #: data 610 640 0410   talk 610 640 9897
Communication Settings: 1200 baud,n,8,1 ASCII format
Data Logger Serial #: DT002070
Data Template file: SOL20.wk3

MONITORING SYSTEM INSPECTION NOTES

System Configuration and Monitoring Points – The monitored system configuration and the monitoring points are shown in figure 1.

Data Logger Channel Table – The data logger channel assignments and calibrations are given in the channel table attached as Table 1.

Solar Exposure and Shading – This site has solar shading from high trees. The PV array is mounted at the base of an East facing roof slope, with a 50 deg tilt to the South. Solar exposure on the PV array is about 50% of full exposure.

Lighting Target Area – The security light is mounted outdoors and aimed at the area near the front door.

Site Measurement, Light Power – Light power measured as 6.34 V at .92 amps. Light power estimated as, watts = 5.83. Bulb resistance, R, is 6.89 ohms. Formula for power as a function of battery voltage is watts = v^2/R.

DEFINITION OF DATA TEMPLATE VARIABLES

Battery Temperature – Mean hourly battery temperature inside the battery box, deg F.
Batt on Battery voltage graph – Mean hourly battery voltage, V. In the range of 6-7 volts.
PV-Batt on Battery Voltage graph – Mean hourly difference between PV voltage and Battery voltage. An hourly graph of this variable shows the activity of the charge control.
Lighting cycles/hr on the Battery voltage graph – Number of times the light is triggered on in the hour
Solar Gain on Energy Input Output graph – Hourly energy output from the PV array into the battery in milliwatthours.
Lighting energy on Energy input/output graph – Hourly energy into the light in milliwatt hours

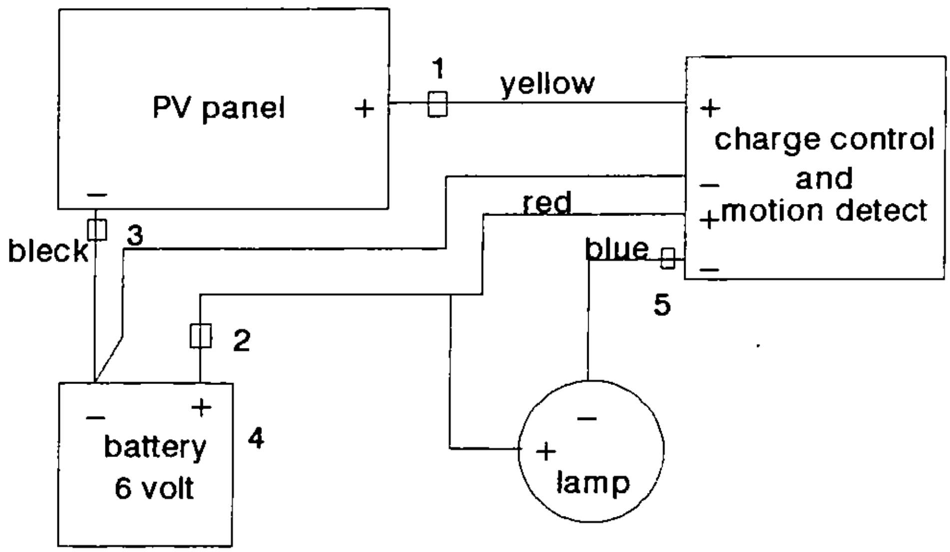


Figure 1. Solar Security Light Schematic

Monitoring Points

1 PV array voltage relative to − battery
2 Battery voltage relative to − battery
3 PV array current, via V on shunt resistor
4 Battery temperature
5 Lamp on/off status, if V<1 lamp on

TABLE 1. DATA LOGGER SET UP PARAMETERS

CURRENT SYSTEM CONFIGURATION

Channels Active:	7	Auto-Dial:	DISABLED
Channels Stored:	7	Day:	
Storage Interval:	60 MINUTES	Time:	
Free Data Storage:	172.2 DAYS	Auto-Answer:	1 RING(S)
Total Data Storage:	304.5 DAYS	Day:	EVERYDAY
Oldest Stored Data:	05/12 24:30	Starting:	00:00
Last Data Download:	07/22 12:00	Ending:	24:00
Baud Rate:	1200 BPS		

Current Time: THURSDAY 07/22/99 22:58:48

Site ID#: SOLAR 2 Unit Serial No.: T002070

#	NAME	UNITS	TYPE	SLOPE	INCPT	'A'	'B'	'C'	'D'	'E'
9	PV Volts	Volts	3	10.16	0.00	0	0	0	0.00	0.00
10	PV mAmps	milliAmp	4	-6200.00	6.00	0	0	0	0.00	0.00
11	BattVolt	Volts	3	10.16	0.00	0	0	0	0.00	0.00
12	Lamp-	Volts	3	10.17	0.00	0	0	0	0.00	0.00
13	BatTemp	Deg.F.	1	1.00	0.00	0	0	0	0.00	0.00
41	Lamp	Status	20	1.00	0.00	0	0	12	0.25	1.30
42	Lamp	Cycles	21	1.00	0.00	41	1	0	0.00	0.00

OUTPUT MENU CHOICES STILL ACTIVE

MONITORING INSTALLATION DOCUMENTATION

MONITORING SYSTEM IDENTIFICATION
System Type: Solar Water Heating System
Installation Report #: 3
Installation Date: October 13, 1999
Installation designation : DHW 1
Location: 24290 Sail View, Elmira Oregon, 97437
Name: Richard and Susan Lemer
Phone #: data 541 935 4024 talk 541 935 4026
Communication Settings: 2400 baud,n,8,1 ASCII format
Data Logger Serial #: DT002033
Data Template file: lemer2.wk3

MONITORING SYSTEM INSPECTION NOTES
System Configuration and Monitoring Points – The monitored system configuration and the monitoring points are shown in figure 1.

Data Logger Channel Table – The data logger channel assignments and calibrations are given in the channel table attached as Table 1.

Solar Exposure and Shading – This site has very good solar exposure with the plane of the solar collectors at 20 degrees almost due south. The 18 watt PV array is mounted at the top of the solar array in the same plane.

Associated One Time Measurements – Solar loop fluid flow is measured by measuring the solar pump voltage. Solar pump voltage versus flow has been measured on site. A regression to the site measurements characterizes solar loop flow by the following function: flow:in gpm = -.09 + .35*V This measurement is unique to the flow resistance at this site. Heat capacity of 50% propelene glycol has been derived from tables to be: .85 BTU/lb deg F. Laboratory measurements of the density of a 50% solution of propelene glycol of 8.43 lbs/volume gallon. Laboratory measurements were also used to validate the visual flow measurements on the solar loop. Laboratory measurements confirm that the solar loop flow meter reads within 2% for both water and 50% glycol.

Site Objectives - This site has been monitored to checkout of the solar DHW monitoring approach and equipment and to check out the possibility of a less expensive but equally viable solar DHW system. This uses an inexpensive external heat exchanger attached to a common DHW tank. The prospective savings from this test configuration are of the order of $500/system in materials.

DEFINITIONS OF DATA TEMPLATE VARIABLES

DHW flow – Hourly DHW flow, gallons.
DHW Energy – Hourly DHW energy output, BTU.
DHW backup Energy – Hourly electrical backup energy, BTU.
Solar Gain – Hourly solar energy collected, BTU
Solar Loop Flow – Hourly mean flow in solar loop, gallons/minute.
Cumulative DHW output – Cumulative DHW output, BTU.
Cumulative DHW input – Cumulative DHW electrical input, BTU.
HX delta T – Mean heat exchanger delta T relative to lowest storage temperature, deg F.
Cumulative Solar Gain – Cumulative solar gain, BTU.
Cumulative Delta T – Cumulative delta T, deghrs.

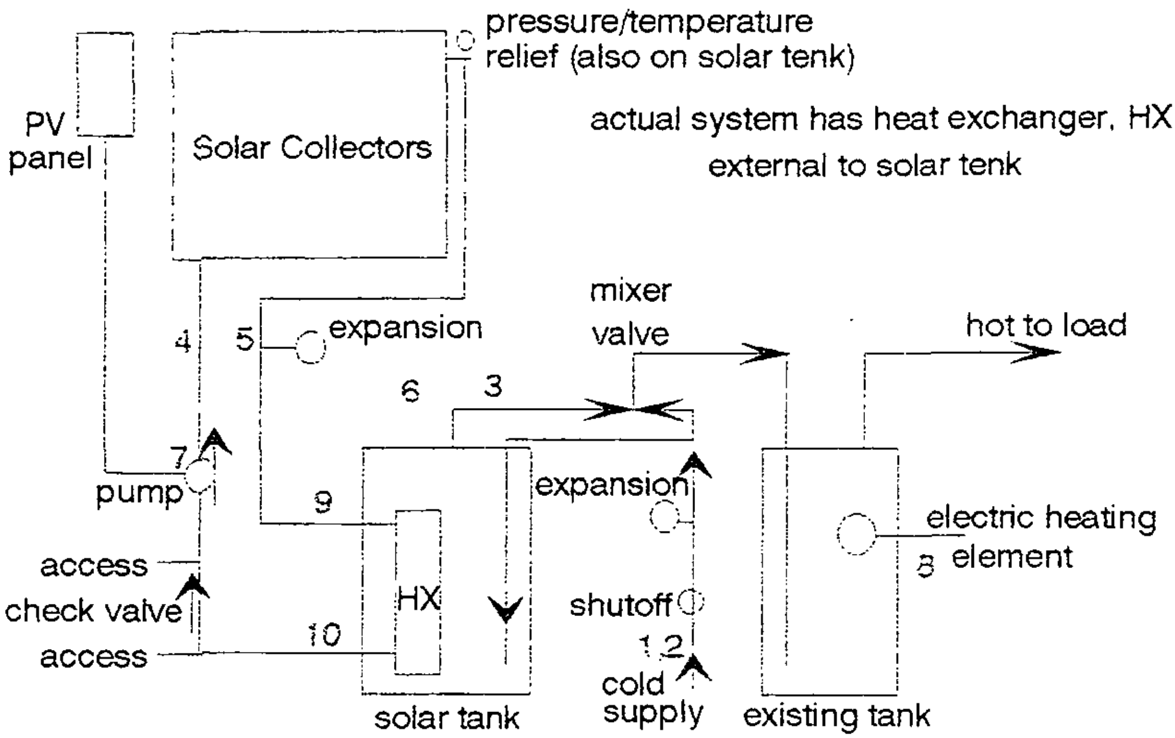


Fig 1. Solar DHW system Schematic with Monitoring Points

Monitoring Points

1 – DHW supply flow
2 – DHW supply water temperature
3 – Solar tank outlet temperature
4 – Flow temperature to solar array
5 – Flow temperature from solar array
6 – Ambient temperature at tanks
7 – DC voltage at solar pump
8 – Element power to existing tank
9 – HX top temperature
10 – HX bottom temperature

TABLE 1. DATA LOGGER SET UP PARAMETERS

#	NAME	UNITS	TYPE	SLOPE	INCPT	'A'	'B'	'C'	'D'	'E'
2	Flow	Gal	8	1.00	0.00	0	0	0	0.00	0.00
9	T inlet	Deg F	1	1.00	0.00	0	0	0	0.00	0.00
10	T hxtop	Deg F	1	1.00	0.20	0	0	0	0.00	0.00
11	T out	Deg F	1	1.00	0.30	0	0	0	0.00	0.00
12	T amb	Deg F	1	1.00	-0.60	0	0	0	0.00	0.00
13	T solup	Deg F	1	1.00	-0.50	0	0	0	0.00	0.00
14	T soldn	Deg F	1	1.00	-0.20	0	0	0	0.00	0.00
15	pmpflo	volts	3	5.00	0.00	0	0	0	0.00	0.00
16	Thx bot	deg F	1	1.00	0.00	0	0	0	0.00	0.00
17	power	watts	2	1.00	0.00	100	0	0	0.00	0.00
41	floind	1/0	121	1.00	0.00	2	0	0	0.00	0.00
42	delT 1	Deg F	112	1.00	0.00	11	9	0	0.00	0.00
43	flostat	1/0	120	1.00	0.00	0	0	15	3.00	10.00
44	btubktnk	btu	113	8.33	0.00	41	42	0	0.00	0.00
45	bk tnk	btu/gal	17	1.00	0.00	44	0	41	0.50	5.00
46	Flo out	deg F	17	1.00	0.00	11	0	41	0.50	5.00
47	fhxtop	deg F	17	1.00	0.00	10	0	43	0.50	5.00
48	polls		10	1.00	0.00	0	0	0	0.00	0.00
49	Tinmin	Deg F	19	1.00	0.00	9	0	0	0.00	0.00
50	fsolup	deg F	17	1.00	0.00	13	0	43	0.50	5.00
51	fsoldn	deg F	17	1.00	0.00	14	0	43	0.50	5.00
52	fhxbot	deg F	17	1.00	0.00	16	0	43	0.50	5.00

OUTPUT MENU CHOICES STILL ACTIVE

MONITORING INSTALLATION DOCUMENTATION

MONITORING SYSTEM IDENTIFICATION

System Type: Solar Water Heating System
Installation Report #: 4
Installation Date: December 13, 1999
Installation designation : DHW 2
Location: 1311 Aldine st, Philadelphia PA, 19111
Name: Susan and Ennil Pontarelli
Phone #: data 215 742 4775 talk 215 742 8901
Communication Settings: 2400 baud,n,8,1 ASCII format
Data Logger Serial #: DT002038
Data Template file: dhw2.wk3

MONITORING SYSTEM INSPECTION NOTES

System Configuration and Monitoring Points – The monitored system configuration and the monitoring points are shown in figure 1.

Data Logger Channel Table – The data logger channel assignments and calibrations are given in the channel table attached as Table 1.

Solar Exposure and Shading – This site has very good solar exposure with the plane of the solar collectors at 20 degrees almost due south. The 18 watt PV array is mounted at the top of the solar array in the same plane.

Associated One Time Measurements – Solar loop fluid flow is measured by measuring the solar pump voltage. Solar pump voltage versus flow has been measured on site. A regression to the site measurements characterizes solar loop flow by the following function: flow:in gpm = -.09 + .35*V (this measurement is based on the measurement at site #3 because no sun was available during installation; a refined measurement will be made under sunny conditions). This measurement is unique to the flow resistance at this site. Heat capacity of 50% propelene glycol has been derived from tables to be: .85 BTU/lb deg F. Laboratory measurements of the density of a 50% solution of propelene glycol of 8.43 lbs/volume gallon. Laboratory measurements were also used to validate the visual flow measurements on the solar loop. Laboratory measurements confirm that the solar loop flow meter reads within 2% for both water and 50% glycol. Laboratory measurements were used to calibrate the inlet flow meter to .975 volume gallons/count.

DEFINITIONS OF DATA TEMPLATE VARIABLES

DHW flow – Hourly DHW flow, gallons.

DHW Energy – Hourly DHW energy output, BTU.

DHW backup Energy – Hourly electrical backup energy, BTU.

Solar Gain – Hourly solar energy collected, BTU

Solar Loop Flow – Hourly mean flow in solar loop, gallons/minute.

Cumulative DHW output – Cumulative DHW output, BTU.

Cumulative DHW input – Cumulative DHW electrical input, BTU.

HX delta T – Mean heat exchanger delta T relative to lowest storage temperature, deg F.

Cumulative Solar Gain – Cumulative solar gain, BTU.

Cumulative Delta T – Cumulative delta T, deghrs.

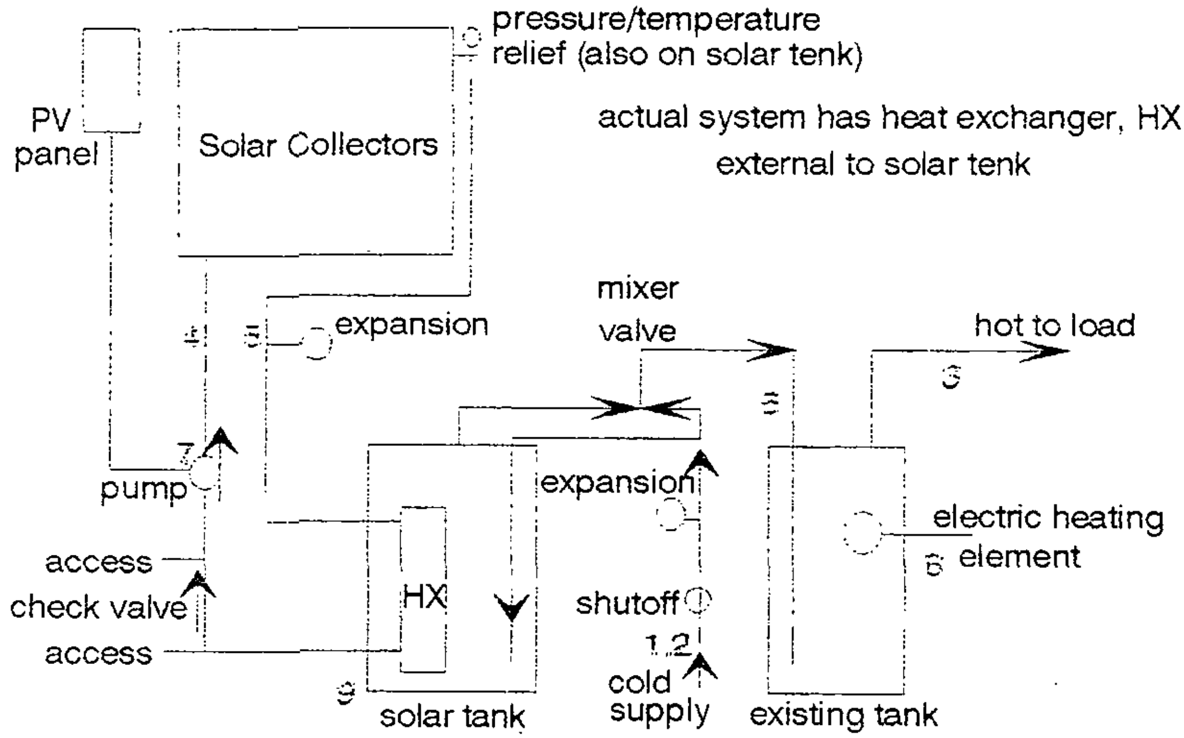


Fig 1. Solar DHW system Schematic with Monitoring Points

Monitoring Points

1 – DHW supply flow
2 – DHW supply water temperature
3 – DHW hot temperature to load
4 – Flow temperature to solar array
5 – Flow temperature from solar array
6 – Solar tank outlet temperature
7 – DC voltage at solar pump
8 – Element power to existing tank
9 – Tank bottom temperature

TABLE 1. DATA LOGGER SET UP PARAMETERS

#	NAME	UNITS	TYPE	SLOPE	INCPT	'A'	'B'	'C'	'D'	'E'
2	Flow	Gallons	8	1.00	0.00	0	0	0	0.00	0.00
9	T inlet	Deg F	1	1.00	2.00	0	0	0	0.00	0.00
10	Tnk out	Deg F	1	1.00	1.30	0	0	0	0.00	0.00
11	DHW out	Deg F	1	1.00	1.40	0	0	0	0.00	0.00
12	T solup	Deg F	1	1.00	0.40	0	0	0	0.00	0.00
13	T soldn	Deg F	1	1.00	1.30	0	0	0	0.00	0.00
14	Tnk bot	Deg F	1	1.00	0.00	0	0	0	0.00	0.00
15	Pmp V	Volts	3	5.00	0.00	0	0	0	0.00	0.00
16	DHW pwr	Watts	2	1.00	0.00	100	0	0	0.00	0.00
41	flo ind	0/1	121	1.00	0.00	2	0	0	0.00	0.00
42	soldlt	deg F	112	1.00	0.00	10	9	0	0.00	0.00
43	DHWdlt	deg F	112	1.00	0.00	11	9	0	0.00	0.00
44	pmpstat	0/1	120	1.00	0.00	0	0	15	3.00	10.00
45	solbtu	btu	113	8.33	0.00	41	42	0	0.00	0.00
46	btudhw	btu	113	8.33	0.00	41	43	0	0.00	0.00
47	soltnk	btu/gal	17	1.00	0.00	45	0	41	0.50	5.00
48	dhwtnk	btu/gal	17	1.00	0.00	46	0	41	0.50	5.00
49	polls		10	1.00	0.00	0	0	0	0.00	0.00
50	tinmin	deg F	19	1.00	0.00	9	0	0	0.00	0.00
51	psolup	deg F	17	1.00	0.00	12	0	44	0.50	5.00
52	psoldn	deg F	17	1.00	0.00	13	0	44	0.50	5.00
53	ptnkbot	deg F	17	1.00	0.00	14	0	44	0.50	5.00
54	Solflo	deg F	113	1.00	0.00	41	10	0	0.00	0.00
55	solflow	deg F	17	1.00	0.00	54	0	41	0.50	5.00

OUTPUT MENU CHOICES STILL ACTIVE

MONITORING INSTALLATION DOCUMENTATION

MONITORING SYSTEM IDENTIFICATION
System Type: Solar Water Heating System
Installation Report: # 5
Installation Date: May 8, 2000
Installation designation : DHW 3
Location: 232 Washington Ave, Milmont Park PA, 19033
Name: Robert Strehlau
Phone #: data 610 534 2539 talk 610 534 7160
Communication Settings: 1200 baud,n,8,1 ASCII format
Data Logger Serial #: DT002070
Data Template file: strehla.xls

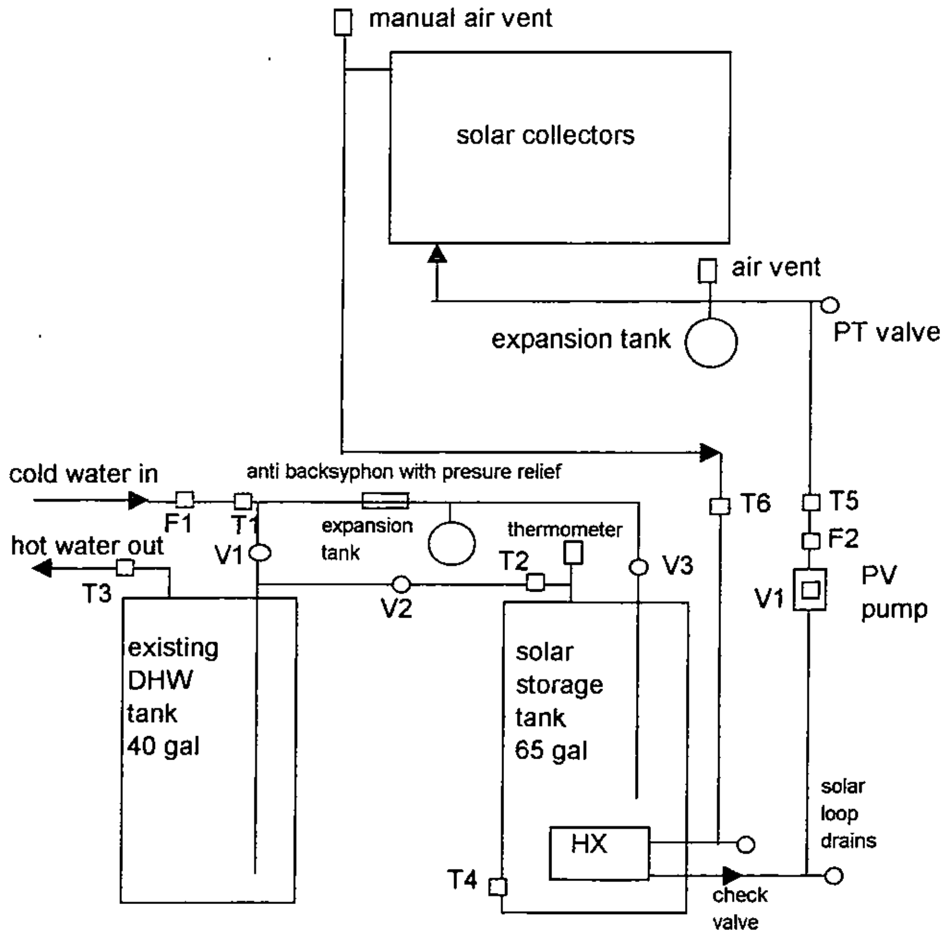
MONITORING SYSTEM INSPECTION NOTES
System Configuration and Monitoring Points – The monitored system configuration and the monitoring points are shown in figure 1.

Data Logger Channel Table – The data logger channel assignments and calibrations are given in the channel table attached as Table 1.

Solar Exposure and Shading – This site has very good solar exposure with the plane of the solar collectors at 40 degrees almost due south. The 10 watt PV array is mounted at the top of the solar array in the same plane.

Associated One Time Measurements – Solar loop fluid flow is measured by measuring the solar pump voltage. Solar pump voltage versus flow has been measured on site. A regression to the site measurements characterizes solar loop flow by the following function: flow in gpm = -.19 + ..1633*V. This function is based on the site measurements detailed in figure 2. This measurement is unique to the flow resistance at this site. Heat capacity of 50% propelene glycol has been derived from tables to be: 85 BTU/lb deg F. Laboratory measurements of the density of a 50% solution of propelene glycol of 8.43 lbs/volume gallon. Laboratory measurements were also used to validate the visual flow measurements on the solar loop. These measurements confirm that the solar loop flow meter reads within 2% for both water and 50% glycol. Laboratory measurements were used to calibrate the inlet flow meter to .975 volume gallons/count.

SOLAR WATER HEATING SYSTEM SCHEMATIC



Isolation Valve Settings

	solar on	solar off
V1	closed	open
V2	open	closed
V3	open	closed

Monitoring Points

T1	logged inlet temperature
T2	logged solar tank outlet temperature
T3	logged DHW outlet temperature
T4	logged tank bottom temperature
T5	logged temperature to solar collectors
T6	logged temperature from solar collectors
F1	logged DHW water flow
F2	visual solar loop flow
V1	logged PV pump voltage

TABLE 1. Data Logger Set Up Parameters

#	NAME	UNITS	TYPE	SLOPE	INCPT	'A'	'B'	'C'	'D'	'E'
2	Flow	Gallons	8	1.00	0.00	0	0	0	0.00	0.00
9	T inlet	Deg F	1	1.00	0.00	0	0	0	0.00	0.00
10	Tnk out	Deg F	1	1.00	1.10	0	0	0	0.00	0.00
11	DHW out	Deg F	1	1.00	0.20	0	0	0	0.00	0.00
12	T solup	Deg F	1	1.00	2.90	0	0	0	0.00	0.00
13	T soldn	Deg F	1	1.00	1.50	0	0	0	0.00	0.00
14	Tnk bot	Deg F	1	1.00	-1.70	0	0	0	0.00	0.00
15	Pmp V	Volts	3	5.00	0.00	0	0	0	0.00	0.00
16	DHW pwr	Watts	2	1.00	0.00	100	0	0	0.00	0.00
41	flo ind	0/1	121	1.00	0.00	2	0	0	0.00	0.00
42	sol dt	deg F	112	1.00	0.00	10	9	0	0.00	0.00
43	DHW dt	deg F	112	1.00	0.00	11	9	0	0.00	0.00
44	pmpstat	0/1	120	1.00	0.00	0	0	.15	3.00	10.00
45	solbtu	btu	113	8.33	0.00	41	42	0	0.00	0.00
46	DHW btu	btu	113	8.33	0.00	41	43	0	0.00	0.00
47	sol tnk	btu/gal	17	1.00	0.00	45	0	41	0.50	5.00
48	DHW tnk	btu/gal	17	1.00	0.00	46	0	41	0.50	5.00
49	polls		10	1.00	0.00	0	0	0	0.00	0.00
50	t inmin	deg F	19	1.00	0.00	9	0	0	0.00	0.00
51	psolup	deg F	17	1.00	0.00	12	0	44	0.50	5.00
52	psoldn	deg F	17	1.00	0.00	13	0	44	0.50	5.00
53	ptnkbot	deg F	17	1.00	0.00	14	0	44	0.50	5.00
54	solflo	deg F	113	1.00	0.00	41	10	0	0.00	0.00
55	solflow	deg F	17	1.00	0.00	54	0	41	0.50	5.00

DEFINITIONS OF DATA TEMPLATE VARIABLES

DHW flow – Hourly DHW flow, gallons.
DHW Energy – Hourly DHW energy output, BTU.
DHW backup Energy – Hourly electrical backup energy, BTU.
Solar Gain – Hourly solar energy collected, BTU
Solar Loop Flow – Hourly mean flow in solar loop, gallons/minute.
Cumulative DHW output – Cumulative DHW output, BTU.
Cumulative DHW input – Cumulative DHW electrical input, BTU.
HX delta T – Mean heat exchanger delta T relative to lowest storage temperature, deg F.
Cumulative Solar Gain – Cumulative solar gain, BTU.
Cumulative Delta T – Cumulative delta T, deghrs.

Appendix C. Solar Security Light Monitoring Summaries

Monitoring Report #1, July 30 1999

"Solar Centurion" Security Light
Location: at monitoring lab
Time: 19 May-22 July 1999
Date Files:

Summary – This was a "shakedown" test of the solar security lights and the logging instrumentation. This test shows an example of "voluntary shutdown"by a unit in response to low battery voltage. On some occasions extensive unexplained triggering was observed. The operation of the charge control was evident during an extended charging only period. A pre-installation checkout of the battery is important to proper installation of a system. Monitoring of battery condition, temperature and net daily charge will be important to diagnosing long term battery performance.

An initial review of solar security light performance is afforded by the included graphs. One security light is designated as site 013 and the other is site 070, both designations from the serial numbers of the data loggers. With respect to the graphic presentation, the following variable definitions apply:
Battery Temperature – Mean hourly battery temperature inside the battery box, deg F.
Batt on Battery voltage graph – Mean hourly battery voltage, V. In the range of 6-7 volts.
PV-Batt on Battery Voltage graph – Mean hourly difference between PV voltage and Battery voltage. An hourly graph of this variable shows the activity of the charge control.
Lighting cycles/hr on the Battery voltage graph – Number of times the light is triggered on in the hour
Solar Gain on Energy Input Output graph – Hourly energy output from the PV array into the battery in milliwatthours.
Lighting energy on Energy input/output graph – Hourly energy into the light in milliwatt hours

Review of the graphic output reveals the following:

1. More than two months of monitoring has been conducted on the two solar security lights provided by CMC. The purpose of this initial monitoring has been to verify the operation of the monitoring equipment and to establish some baseline experience on the operation of the solar security lights. This monitoring has provided some important experience in the operation of these security lights which should be understood at the outset in-order to assure a successful application.

2. Please note the enclosed performance graphs, In these graphs one light is designated as site 013 and the other light is designated as site 070. These site designations are derived from the serial numbers of the data loggers. These graphs show some key aspects of the operation of these lights from 19 May 1999 to 28 June 1999. The monitored variables presented in the graphs are not all the monitored data. They are a subset of the data intended to facilitate a routine review of the long term performance of the lights. Unusual changes in the patterns of these variables can indicate significant changes in the operation of the equipment, which can then be explored through a more detailed analysis of the data.

3. For both sites the graphs for the period of 19 May to 4 June show a very significant event: By chance, the lights were left in an operating mode on an office window sill in an untended operating mode for at least ten days. This chance event constituted a rather severe test of the lights because the units got quite hot in the sun, and because they were not properly set up (oriented to the sun) and they did not collect as much electricity as they used. This situation resulted in a declining battery voltage which caused both lights to cease functioning after only five days. This cessation of function is a self-protective feature of the product intended to protect the battery from over-discharging. This is a common and necessary feature in any good quality battery charging control. It is important to recognize that this self protection feature can render these lights unexpectedly inoperative in times of low sun and high usage.

4. After several days of battery charging, the lights automatically restored to proper operation (as seen in the graphs for the period 5 June to 27 June). But the fact remains that the proper design operation of these lights includes an automatic cessation of operation after a few days when the energy required by the lights exceeds the energy collected from the sun. It is likely that these lights will cease operating in a low sun /high usage situation. They should be placed in a critical security context cautiously only after assuring that there is no winter shading and that the light will trigger on less than 10-15 times a night..

5. Another observation in the graphs for 19 May to 4 June, is that the lights appear to be triggering more than 30 times in an evening in a vacant office. This is probably "false triggering" caused by the operation of the heating system in the office or by automobiles outside the office window. But this event highlights the need to assure that the occupancy sensor is carefully aimed to avoid false triggering which would drain the battery and lead to a temporary cessation of lighting functions. It should also be noted that the triggering cannot be properly tested during installation unless the battery is almost fully charged. If, by chance, the control switch has been set to any position but "off" during shipment or storage, it is probable that the battery will be discharged and possibly deteriorated. The proper installation of these lights should include a pre-installation checkout of the battery condition and battery charging if necessary.

6. It appears that this light has been designed to operate for up to a week with insufficient solar gain, and this may be a reasonable design margin for general applications. But this design operation in wintertime is contingent on proper orientation of the solar panel (no winter shading) and proper orientation of the occupancy sensor. In my view, critical security applications would be better served by a "beefed up" version of the light with a larger solar panel and a larger battery, all of which could be readily assembled from off-the-shelf components. In any event, interviews and inspections pertaining to these lights should include winter experience when the automatic shutdowns are most likely to occur.

7. At the conclusion of the measurements one of the PV panels was dropped from about 3 foot height. The active element of the panel broke in half, it produced 0 volts in full sun. It appears that this is thin film PV cell applied to un-tempered glass. This glazing appears to be somewhat fragile; durability may be a problem and participant interviews or inspections should check the integrity of the PV panel.

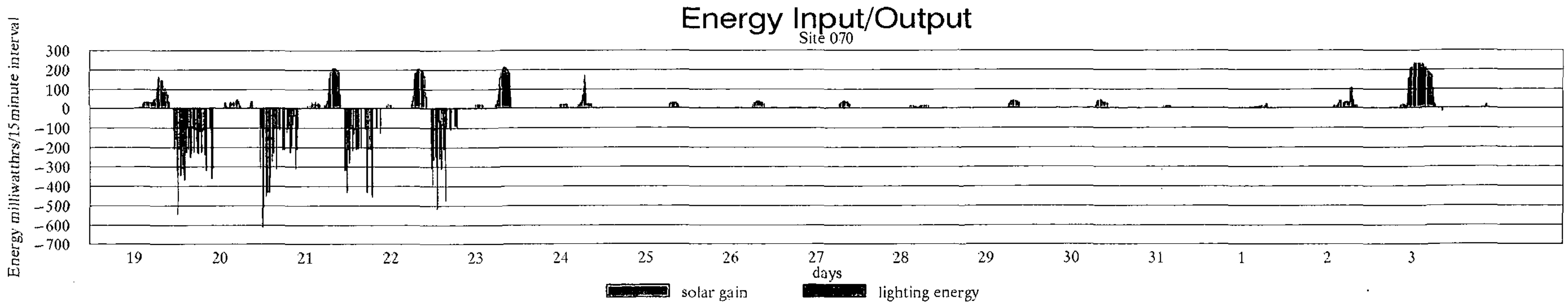
8. From the perspective of long term monitoring, battery condition and lighting energy use and frequency of triggering are important monitoring objectives. Successful operation of the security light depends on maintaining a balance between electrical energy into and out of the battery. The wattage of the halide bulb needs to be measured on a one-time basis in-order to log the energy output of the battery. The overall energy balance at the battery must include battery self discharge energy.

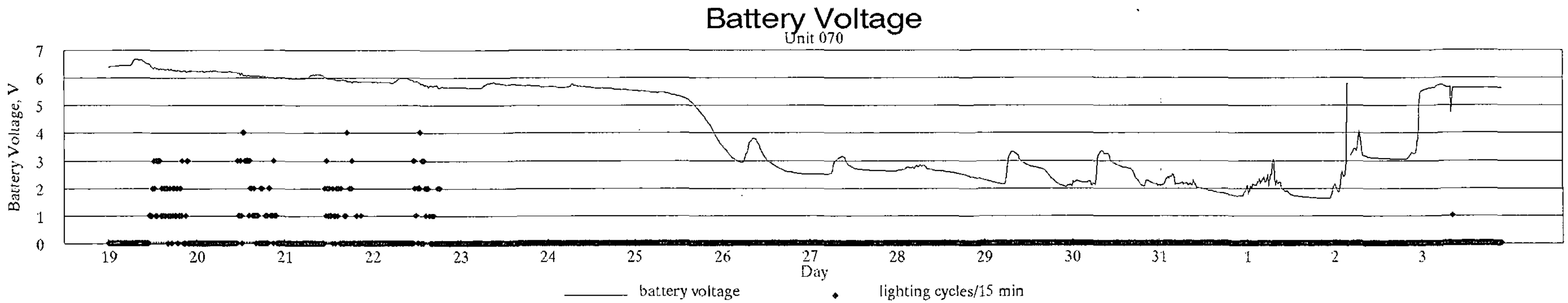
9. The operation of the charge control is clear on the graph for site 013 starting on June 28. On July 11,12, and 13, the voltage of a fully charged battery will increase to about 6.5 volts, then the solar gain will decrease significantly, and the PV-batt will increase. This indicates that the charge controller is reducing the current input to the battery by by increasing the resistive load on the PV panel.

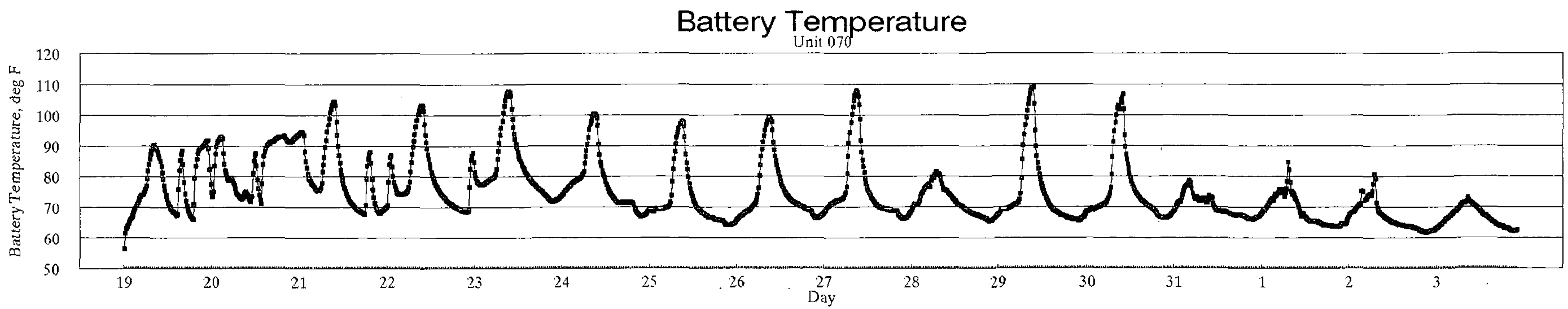
BI-MONTHLY MONITORING SUMMARY

Site: 070 | Start Date: month 5, day 19, hour 9

Observations: Lighting energy exceeded solar gain, automatic lighting operation stopped after day 5. Battery failure to charge after day 5.





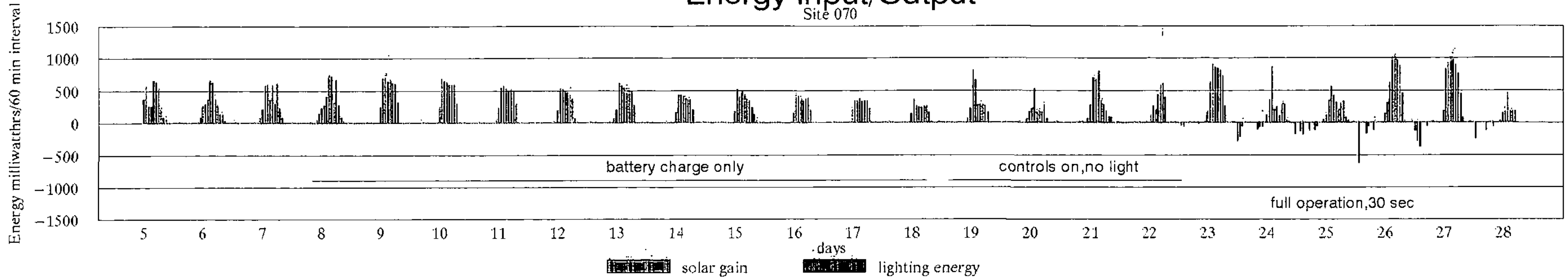


BI-MONTHLY MONITORING SUMMARY

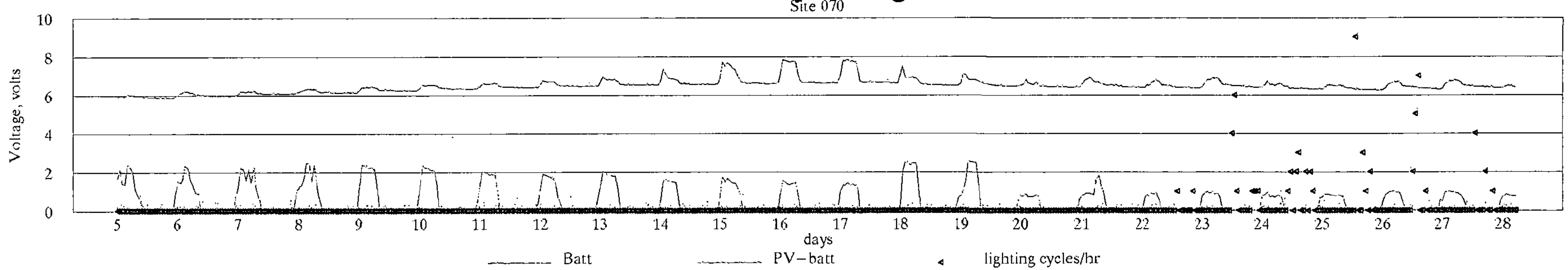
Site: 070 | Start Date: month 6, day 5, hour 10

Observations: Light turned off most of period. Overcharge may be occuring from 13-18.
Automatic lighting control enabled after 19, but very little night activity.
Full operation with light interval @ 30 sec

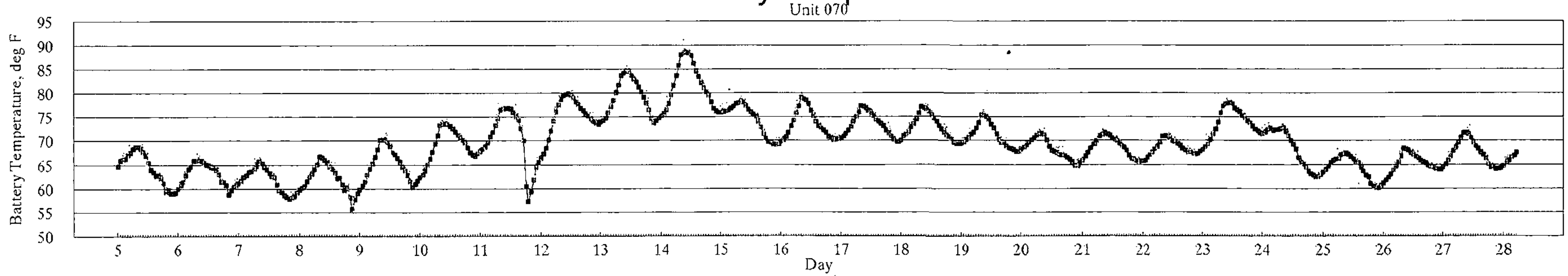
Energy Input/Output



Battery Voltage



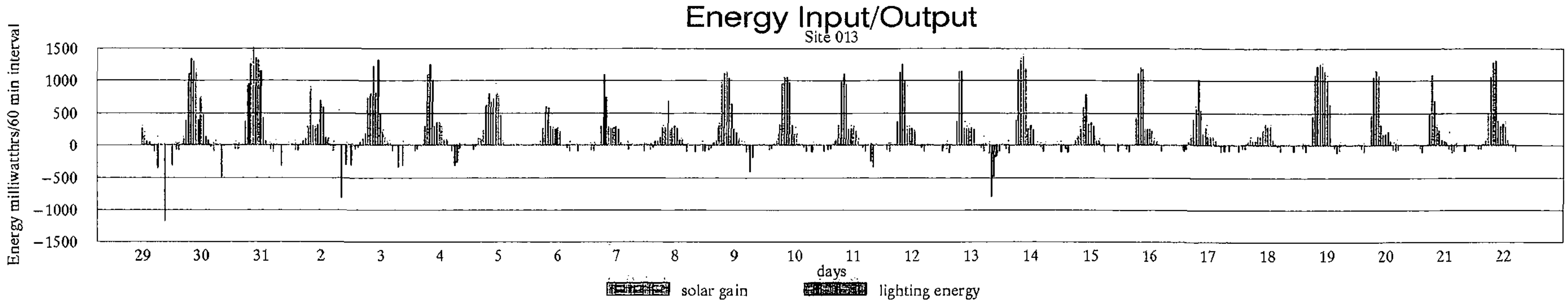
Battery Temperature

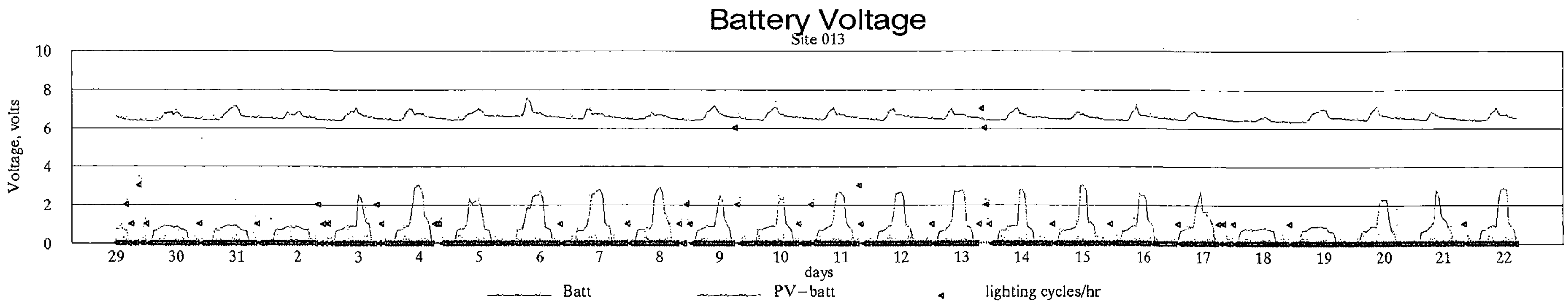


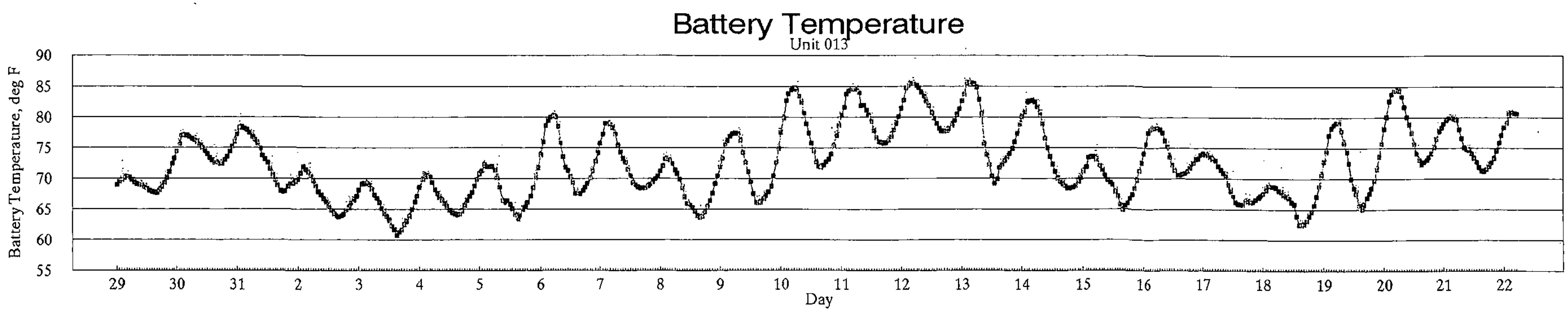
BI–MONTHLY MONITORING SUMMARY

Site: 013 Start Date: month 6, day 28, hour 16

Observations: Automatic operation with 3 minute light period. Operation of charge control is quite clear from July 10–July 14.







Monitoring Report #2, December 14, 1999

"Solar Centurion" Security Light
Location: at two Philadelphia sites
Time: 24 July-15 November 1999
Data Files: pecol7a.wk3, pecol8a.wk3, pecol9a,wk3, peco75a.wk3, peco76a.wk3

Summary – This was a real world test of the solar security lights prior to full scale program implementation. At the time of this report, the test has been in place for four months. This test shows that the lights can be expected to operate properly in full solar illumination conditions only in spring, summer, and fall. It is therefore recommended that these lights not be used in a security lighting context in the Philadelphia climate. Continuing monitoring will determine if winter low light conditions lead to permanent battery damage and reduced product life. The lights appear to be under designed for the intended mission. A properly designed lighting system can be expected to cost in the range of $750-$1,000.

One light was installed in poor solar illumination conditions and the low battery voltage was evident within two weeks of installation. This low battery voltage deteriorated the battery and the light failed.

The second installation had very good solar conditions and reasonably heavy usage of the lighting. This installation performed well during summer and fall, but began to fail in winter as the battery voltage dropped below 6 volts. It appears that even with good solar conditions the light cannot be relied on in winter.

The first (and failed) security light installation was decommissioned in December 1999. The second light remains monitored even though the lighting operation has ceased. This continued monitoring is intended to detect battery deterioration under low light conditions.

A specific review of solar security light performance is afforded by the included graphs. One security light is designated as site 013 and the other is site 070, both designations from the serial numbers of the data loggers. With respect to the graphic presentation, the following variable definitions apply:
Battery Temperature – Mean hourly battery temperature inside the battery box, deg F.
Batt on Battery voltage graph – Mean hourly battery voltage, V. In the range of 6-7 volts.
PV-Batt on Battery Voltage graph – Mean hourly difference between PV voltage and Battery voltage. An hourly graph of this variable shows the activity of the charge control.
Lighting cycles/hr on the Battery voltage graph – Number of times the light is triggered on in the hour
Solar Gain on Energy Input Output graph – Hourly energy output from the PV array into the battery in milliwatthours.
Lighting energy on Energy input/output graph – Hourly energy into the light in milliwatt hours

Review of the graphic output reveals the following:

1. More than four months of monitoring under actual Philadelphia site conditions has been conducted on the two solar security lights provided by CMC. The purpose of this initial monitoring has been to verify the operation of the monitoring equipment and to establish some baseline experience on the operation of the solar security lights. This monitoring has provided some conslusive experience in the operation of these security lights.

2. Please note the enclosed performance graphs, In these graphs one light is designated as site 013 and the other light is designated as site 070. These site designations are derived from the serial numbers of the data loggers. These graphs show some key aspects of the operation of these lights from 23 July 1999 to 15 November 1999. The monitored variables presented in the graphs are not all the monitored data. They are a subset of the data intended to facilitate a routine review of the long term performance of the lights. Unusual changes in the patterns of these variables can indicate significant changes in the operation of the equipment, which can then be explored through a more detailed analysis of the data.

3. The site designated as 013 shows very good operation through the summer and until the end of October. Through this time period the incident solar gain was consistent enough and strong enough to maintain a battery voltage of over 6 volts. However in November the incident solar even on sunny days diminished and the battery voltage gradually decreased to just under 6 volts. The lighting operation became somewhat erratic as the automatic lighting operation was suppressed by the controller in-order to protect the battery. By December the lighting operation had almost ceased. This site will continue to be monitored through the months of December, January, and February in-order to track the battery voltage through the deepest portions of winter. If the battery voltage falls into the 2-4 volt range, there is evidence that the battery is undergoing irreversible chemical changes. These changes will significantly shorten the battery life to a one or two season application only.

4. The site designated 070 shows poor performance almost from the beginning. The PV panel at this site was deliberately installed at a location with limited solar exposure. The solar exposure at this site consisted of 3-4 hours of full sun in the summer, but the large surrounding trees began to shade the site by early fall. It was quickly evident in the graphs that anything but full sun could not maintain the battery charge. The light began to fail within one month of installation. The battery voltage at this site has ranged from 2-4 volts for the last two months. The site was de-commissioned in December 1999. It is recommended that the battery from this site be removed and tested to confirm battery degradation. .

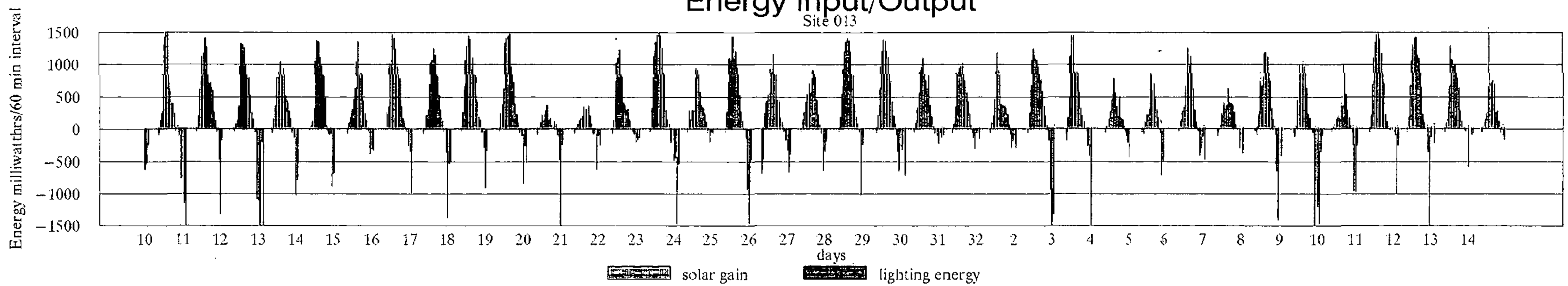
5. It is probable that these inexpensive solar security lights have been seriously under designed for the climate. As a check on this premise, a firm specializing in the custom design of solar security lighting was contacted. This firm provided a design for a hypothetical security lighting application in the Philadelphia area and a price quote for such an application. It is apparent that a well designed custom application for this area would cost in the range of $750-1000/site.

BI–MONTHLY MONITORING SUMMARY

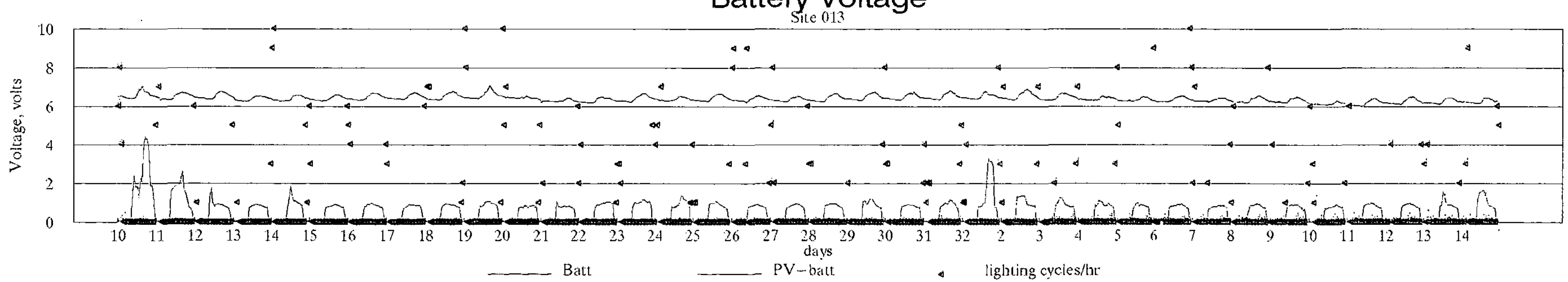
Site: 013 | Start Date: month 8, day 9, hour 19

Observations: Automatic operation with 3 minute light period. Extensive lighting triggering and good battery voltage and charge. Preponderance of charge over lighting energy.

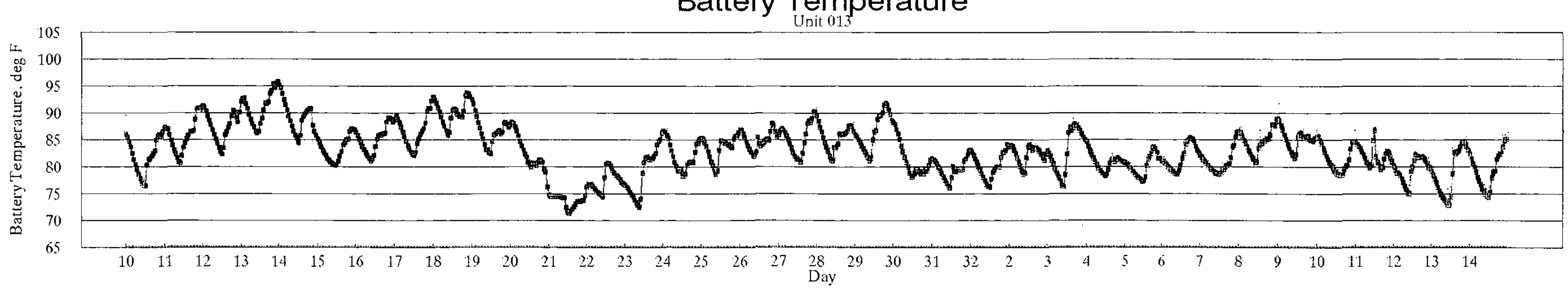
Energy Input/Output



Battery Voltage



Battery Temperature



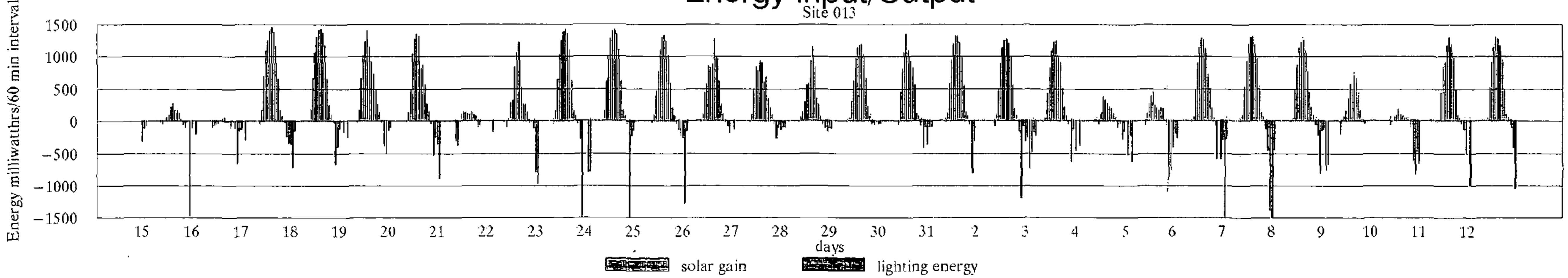
BI–MONTHLY MONITORING SUMMARY

Site: 013

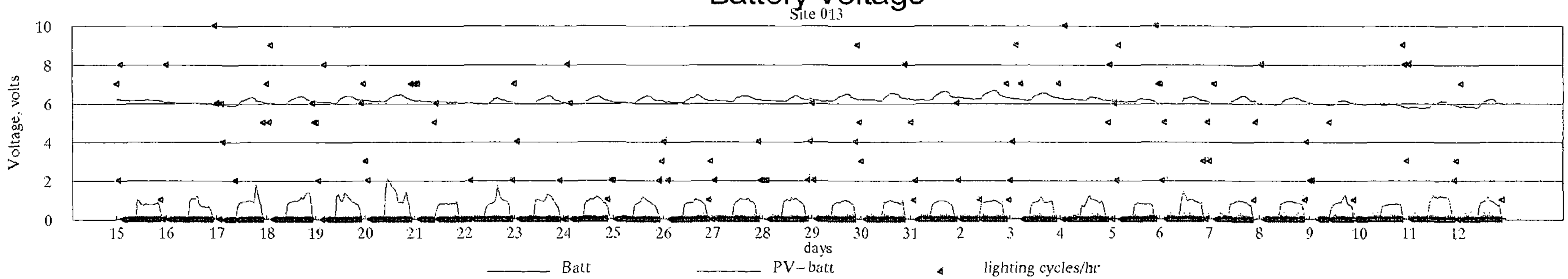
Start Date: month 9, day 14, hour 19

Observations: Automatic operation with 3 minute light period. Extensive lighting triggering and good battery voltage and charge. Preponderance of charge over lighting energy. Battery voltage is trending below 6 volts.

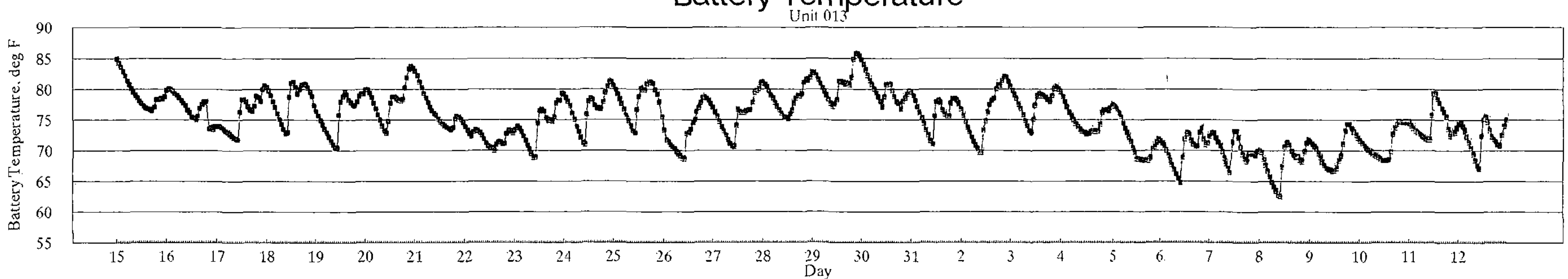
Energy Input/Output



Battery Voltage



Battery Temperature

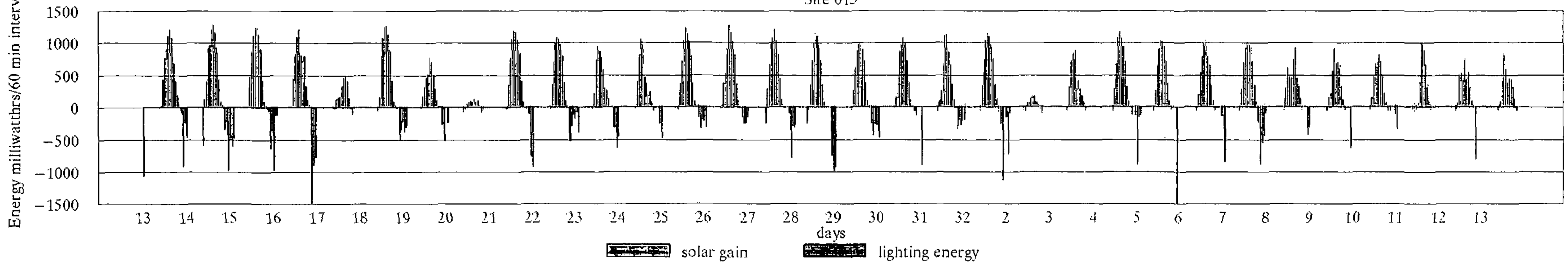


BI–MONTHLY MONITORING SUMMARY

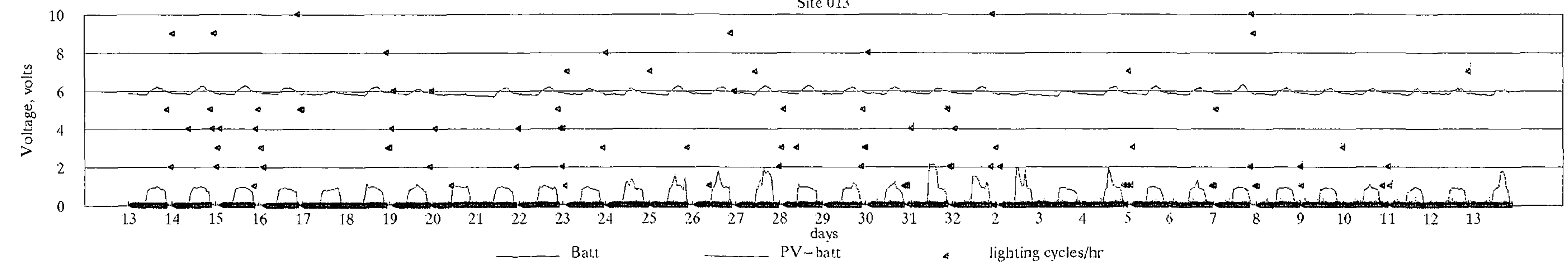
Site: 013 | Start Date: month 10, day 12, hour 19

Observations: Automatic operation with 3 minute light period. Extensive lighting triggering. Battery voltage in late October is 6 Volts + or –, but voltage in November is generally below 6 Volts. Automatic lighting operation in mid November is becoming sporadic.

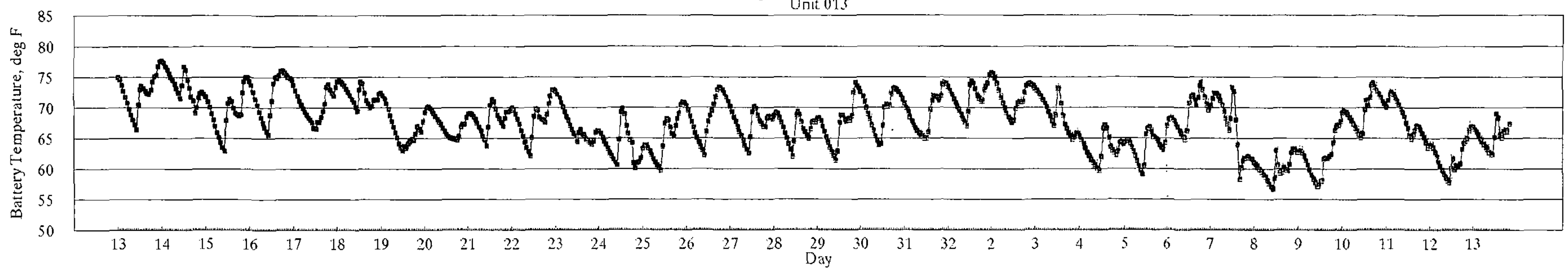
Energy Input/Output
Site 013



Battery Voltage
Site 013



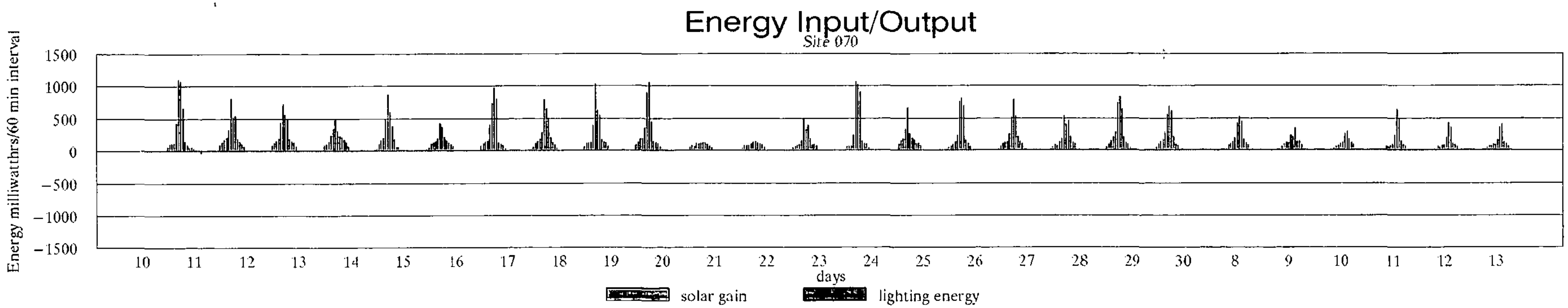
Battery Temperature
Unit 013

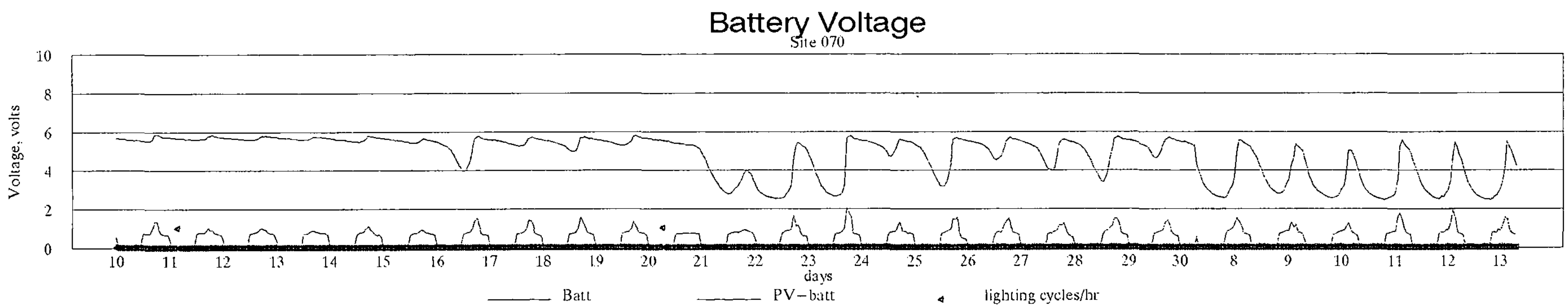


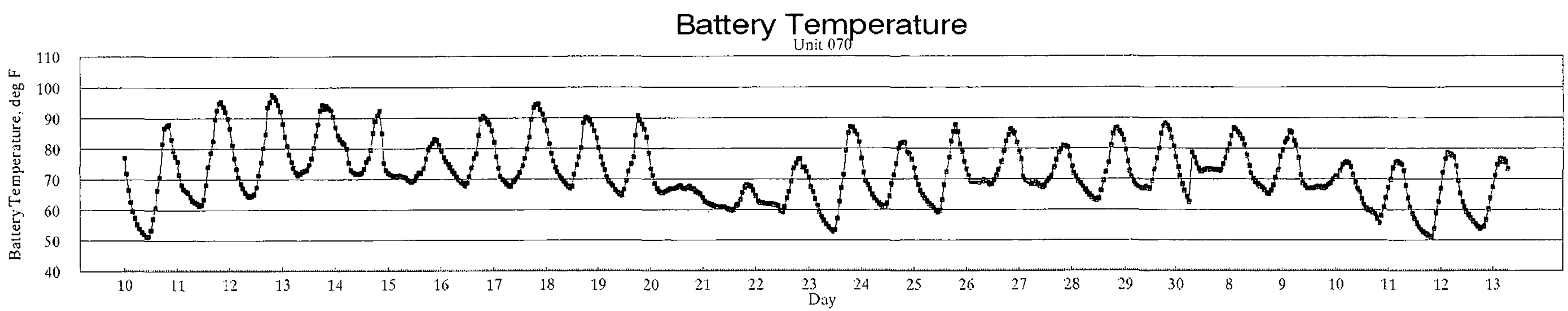
BI–MONTHLY MONITORING SUMMARY

Site: 070 | Start Date: month 8, day 9, hour 17

Observations: Light doesn't turn on, and battery voltage is well below specifications. Battery charging cycle is irregular. Strong charge current is accompanied by large difference in voltage between the PV panel and battery. Probable battery resistance due to battery degradation.



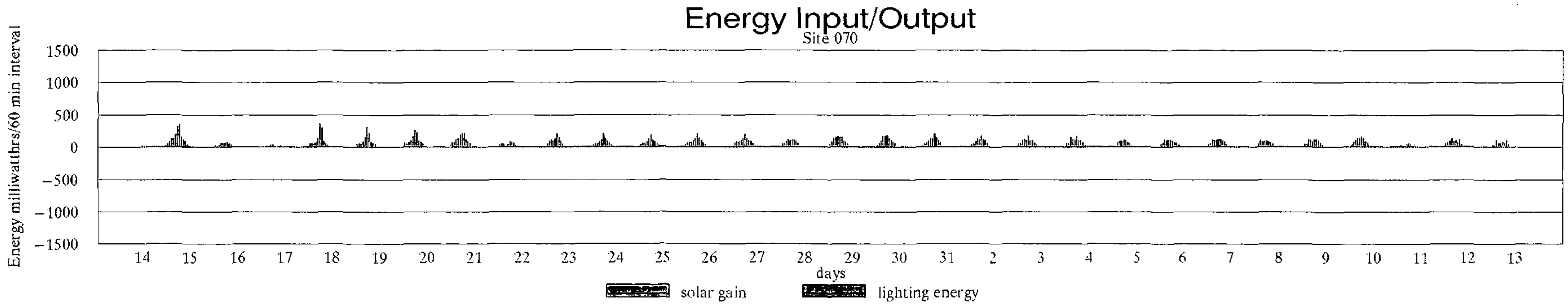


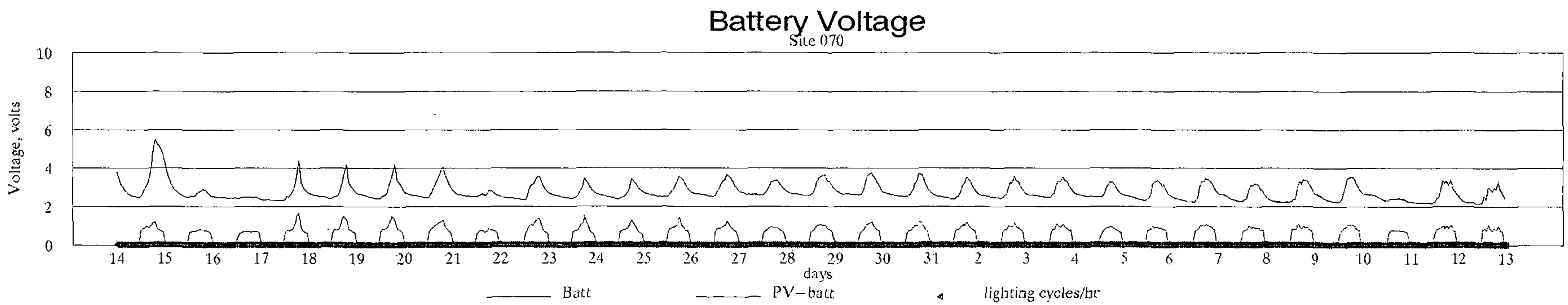


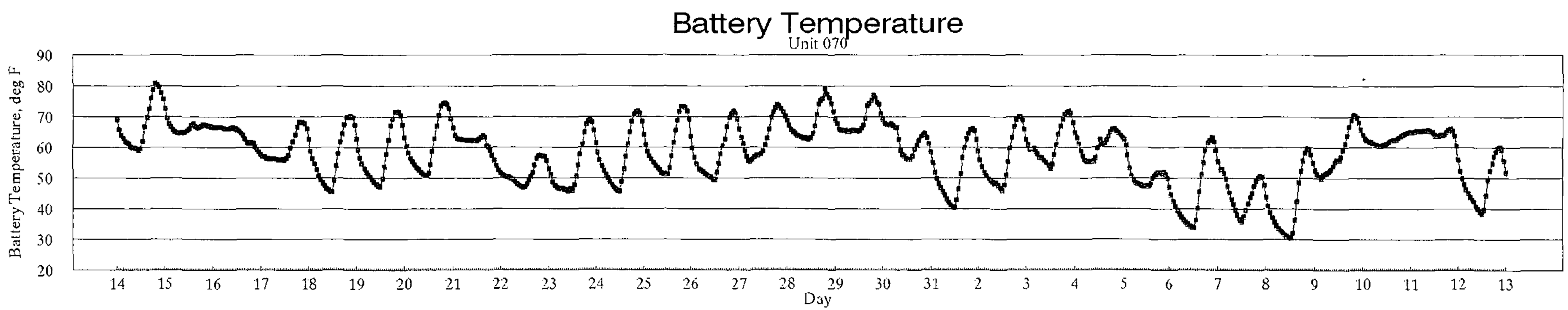
BI–MONTHLY MONITORING SUMMARY

Site: 070	Start Date:	month	9
		day	13
		hour	17

Observations: Light doesn't turn on, and battery voltage is way below specifications. Solar gain is also well below specifications due to extensive shading. Battery is probably not able to retain charge.







APPENDIX A

System Design Parameters and Price Quote for an Adequately Designed Solar Security Lighting System for the Philadelphia Area

Fax

Date: Friday, October 15, 1999

To: PECO
Howard Richmond
Phone: 541-490-3175
Fax: 541-386-4472

From: Solar Outdoor Lighting
Alan Hurst
Phone: 561-286-9461
Fax: 561-286-9616

Pages: 5

Subject:

Please find attached two quotes for lights for the Philadelphia area.
Both are similarly priced, one has the motion detector, one does now.
SOL enjoys a working relationship with several utilities, most operating under this new need to use some pv. However, all are pleased with the results. I have also attached some other government references.

PECO needs to use reliable product to maintain its own reputation.
SOL product is also UL Listed.

Alan Hurst

QUOTATION/PURCHASE ORDER Date: 10/15/99

To: Howard Richmond
From: Alan Hurst
Subject: Security Lighting

Proposal #9910153
Hours of operation: 2 Lamp size: 18 watts fluorescent**
Sunhours: 2.9

Product: SOL EPU-20-MD (Motion Detector)
Price: $1200
Pole: Not included
Installation: Not included
Shipping: $80

SOL system is UL Listed. Batteries are gel cell, require no maintenance.
SOL Max-Lite Reflector assures brightest possible light.
**18 watt bulb is plenty for this size product with Max-Lite Reflector.
Terms are net 30. Shipping in 4-5 weeks.
Price firm for 30 days.

Prepared by: ____________
Alan Hurst

Accepted this _____ day of October, 1999

by ______________________

SOLAR OUTDOOR LIGHTING, INC.
FEDERAL GOVERNMENT INSTALLATIONS

Agency	Location	Application
Army	Yuma Proving Ground, AZ	Streets, Parking, Rec Area
	Natick Labs, MA	Parking
	Rocky Mt. Arsenal, CO	Parking, Remote Security
	Aberdeen Proving Ground, MD	Fuel Station
	Torii Station, Okinawa	Security
	Fort Hood, TX	Parking
Corps of Engineers	Mobile District	Recreation, Boat Launch
	Little Rock District	Recreation, Boat Launch
	Fort Worth District	Recreation, Boat Launch
	Seattle District	Military, Flashing Beacons
	Baltimore District	Restroom and Boat Launch
	St. Louis District	Recreation, Boat Launch
Navy	Colts Neck NWS, NJ	Streets, Storage, Piers
	Miramar NAS, CA	Ammunition Storage
	San Diego NAS (No. Island), CA	Ammunition Storage
	San Diego NAS (No. Island), CA	HazMat Storage
	San Diego NAS (No. Island), CA	Sign Lighting
	Dam Neck, Fleet Training, VA	HazMat Storage
	Oceana NAS, VA	Beacon, Airport Tower
	Oceana NAS, VA	Parking, Air Operations Bldg
	Spain	Sign, Security Area
	Egypt	Remote Site Security
	Dahlgren, VA	Remote Site Security
	Gulfport Const. Battalion, MS	Signs, Housing Area
	Thurmont, MD	Signs, Housing
	Pearl Harbor Shipyard, HI	Signs, Harbor Warning
Air Force	Tinker AFB, OK	Rec Area, Base Housing
	Westover AFB, MA	Parking
	Andersen AFB, Guam	Streets, Parking
	Charleston AFB, SC	Jogging Trail
	Illinois Air National Guard	Traffic Warning Signal
	Dyess AFB, TX	Parking
	Los Angeles AFS, CA	Parking
	Canaveral AFS, FL	Security, Launch Area

Marine Corps	San Diego, CA	Parking, Reserve Center
	Albany Logistics Base, GA	Parking
	Yuma Air Station, AZ	Memorial
	Quantico Base, VA	Road intersection
	Parris Island, SC	Boat Launch
Coast Guard	Petaluma, CA	Parking, Training Center
NASA	Kennedy Space Center, FL	Security, Perimeter Fencing
TVA	Knoxville, TN	Entrance Sign
Justice	Miami Correctional Center	Streets, Parking
	Bureau of Prisons (Unicor), CO	Entrance Sign
FAA	Washington State	Remote Security Area
Park Service	Lake Meredith NRA, TX	Recreation, Boat Launch
	Coulee Dam NRA, WA	Recreation, Boat Launch
	Natchez Trace Parkway, MS	Streets, Intersections
	Whiskeytown/Shasta NRA, CA	Parking, Boat Launch
	Biscayne NP, FL	Interior Restroom
	Lake Mead NRA, NV	Parking, Boat Launch
	Chamizal NM, TX	Pathway
	Mammoth Cave NP, KY	Boat Launch
	Chiricahua NM, AZ	Sign, Camping Information
Fish & Wildlife	Merritt Island Refuge, FL	Recreation, Boat Launch
	Patuxent Research Refuge, MD	Parking, Visitor Center
Bureau of Land Mgt	Coeur d' Alene, ID	Restroom and Boat Launch
Forest Service	Bankhead Ranger District, AL	Recreation, Boat Launch
	London Ranger District, KY	Recreation, Boat Launch
	Seminole Ranger District, FL	Security, Interior Restroom
	Oconee Ranger District, GA	Pay Station Security
	Dixie National Forest, UT	Interior Restroom
	Uncompahgre, CO	Tunnel
GSA	Atlanta, GA	Parking, Security
	Columbus, OH	Parking, Security
	Orlando, FL	Parking, Security
	Honolulu, HI	Parking, Security
	Puerto Rico (Two Sites)	Parking, Security
	Virgin Islands	Parking, Security

Appendix D. Solar DHW Monitoring Summaries

Monitoring Report #3, March 4, 2000

Solar Domestic Hot Water Heater
Location: at one Philadelphia site and at one Oregon site
Time: 31 December 1999-03 March 2000
Data Files: pont2a.xls, pont3a.xls, lemer3.xls

Summary – This monitoring for the winter months of January and February shows the solar water heating system operating as expected. The hot water usage at the test site of 85 gallons/day is typical for a family of 5. The mean hot water temperature of 115 deg F is somewhat lower than typical and may be due to the lockout of the electric element during peak periods. There is no evidence of significant or unusual thermal losses from either the solar tank or the DHW tank. The heat exchanger, which is expected to be one of the best available, is showing good performance. Overall, the solar contribution for January was 21% and for February 31%.

A second site near Eugene Oregon was monitored to verify and test the monitoring approach and to examine a potential cost saving option involving an external heat exchanger and an inexpensive and smaller solar storage tenk. This monitoring showed that the initial candidate heat exchanger was too small. The initial heat exchanger was replaced by a larger one which shows much better results. Monitoring at this Oregon site continues to examine the performance of the improved external heat exchanger.

Monitoring at both sites awaits sunnier weather when a precise PV pump calibration can be done. This improved calibration will applied after the fact to the monitored data. It is not expected to alter the summary results.

A specific review of the solar hot water heater performance is afforded by the included graphs and summary data. With respect to the summary data and graphic presentations, the following variable definitions apply:
Mean Inlet Temp – Mean temperature of the water as it enters the hot water heating system, deg F.
Mean Outlet Temp – Mean temperature of the hot water exiting the hot water heating tank, deg F.
Mean DHW Usage – Mean daily flow of water through the hot water heating system, gallons/day. A graph titled "DHW Flow" shows the cumulative flow of water through the hot water heating system during the monthly monitoring period. This graph will show a straight sloping line if the usage has been constant from day to day. A noticeable curve or angle in this graph indicates a change in hot water usage behavior.
Mean DHW BTU/day – Mean daily energy associated used to heat water. This is the total energy used to heat the hot water, including the solar energy contribution. The graph titled "Cumulative Energy" shows the cumulative energy used to heat water throughout the monthly monitoring period. This blue line on this graph will be a straight sloping line

if the hot water heating energy has been constant from day to day. A noticeable curve or angle in this graph indicates a change in the operation of the hot water heating system.
Mean Solar BTU/day – Mean daily solar contribution toward hot water heating energy. Usually the solar contribution will vary significantly from day to day with the solar conditions. The graph titled"Cumulative energy" includes a red line to show the solar contribution to the hot water heating energy. A straight sloping line here indicates consistent daya to day performance by the solar water heater. A noticeable curve or angle indicates a change in the operation of the solar water heating system.
Solar Contribution – This is the portion, expressed as percent, of the water heating energy load contributed by solar energy. In essence this is the bottom line of the monitoring.
HX Performance – This is a measure of the average monthly performance of the heat exchanger component of the solar water heating system. It is expressed in BTU/deghr to provide a relative measure of the flow of thermal energy through the heat exchanger in response to a temperature difference between the fluid in the solar loop and the tempeature at the bottom of the tank. Ideally, a heat exchanger can be quite complex to monitor because its performance will depend on many factors which are very difficult to monitor, such as natural convection or thermal stratification in the storage tank. Rigorous monitoring of heat exchanger performance is well beyond the scope of this project, due to the needs for complex monitoring and modeling. But some form of comparative heat exchanger monitoring is necessary to validate the proper operation of the system from month to month, and to provide a basis for comparing the operation of systems with different types of heat exchangers. This HX performance parameter is readily established by simple monitoring and it will serve the needs for a comparative heat exchanger performance measurement. The red line on the graph titled "HX Performance" shows the cumulative heat exchange throughput in response to the cumulative temperature difference between the solar fluid and the tank bottom. A noticeable curve or angle in the red line indicates a change in the operation of the heat exchanger during the monthly monitoring period.
DHW Tank Factor – The DHW tank factor measures the losses from the DHW tank to the surrounding space and the connected piping. This factor is defined as the total energy withdrawn from the tank divided by the total energy input to the tank, including all energy input to the tank by the electric element. A good modern tank under typical conditions would have a factor of .93. Typical tanks have factors from .8 to .9.
Solar Tank Factor - The Solar Tank factor measures the losses from the solar tank to the surrounding space and through the connected piping. This factor is defined as the total energy withdrawn from the solar tank divided by the energy input to the solar tank. This factor will vary seasonally with the temperature of the solar tank. The principal use of this factor is to detect thermal losses at night from the solar tank to the solar collectors. Values of this factor below .8 are indicators of potential thermal loss modes.
Daily Energy Flows – The graphs titled "DAILY ENERGY FLOWS" show the the total energy drawn from the DHW system as a blue line and the total solar energy input to the system as a red line. These energy flows are expressed as BTU/hour.

Review of the summary and graphic output reveals the following:

1. At Philadelphia, DHW2 - Two winter months of monitoring under actual Philadelphia usage and site conditions shows the solar water heater producing a 21% contribution for January and a 31% solar contribution for February. This is consistent with the design expectation for this system. The solar contribution can reasonably be expected to increase significantly as the year proceeds.

2. At Philadelphia, DHW2 - The hot water usage at this installation, ranging from 85 to 110 gallons/day, is typical for a family of five. The mean outlet temperature of 112-115 deg F is somewhat lower than would be expected from a hot water heater with a thermostat typically set at 120 deg F or higher. Partly this lower than expected outlet temperature is due to a significant use of hot water during the peak interval when the electric heating elements are disengaged. Also the hot water thermostat has not yet been restored to a higher setting from its low prior setting. Prior to the installation of the solar system the homeowners had reduced the thermostat setting in an attempt to save on electric costs.

3. At Philadelphia, DHW2 - The DHW tank exhibits losses of the order of 15% which is typical for such a tank. The solar tank exhibits losses of only a few percent which is typical for this time of year. There is no indication of night losses from the solar tank to the roof mounted solar panels.

4. At Philadelphia, DHW2 - The heat exchanger shows a higher average performance factor for January than for February. Careful examination of the hourly heat exchanger performance shows that the performance is highest in the morning and diminishes throughout the day as energy is stored in the solar storage tank. This is typical for this type of heat exchanger performance measure which is referenced to the low and relatively constant temperatures at the bottom of the tank. This type of heat exchanger measure is intended to capture the broad effects of the location of the heat exchanger relative to the tank and the size of the heat exchanger relative to the size of the tank. Heat exchanger operation observed so far shows good operation as expected. The heat exchanger is a major design consideration in the system and it can have a significant effect on the efficiency of the system. Following the heat exchanger performance month to month and from system type to system type is expected to be valuable in confirming or modifying system design decisions.

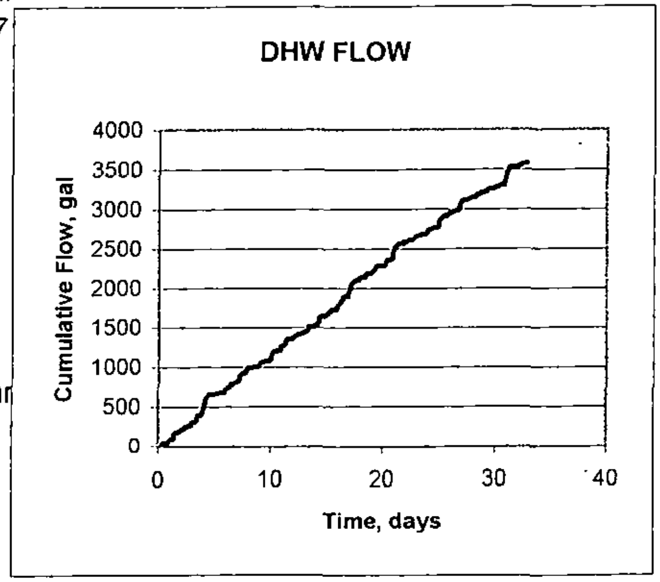
5. At Eugene, DHW1 – Monitoring at this site is limited to the solar storage tank and the heat exchanger. Early monitoring at this site has showed a high dhw use of 165 gallons/day. There has been little solar collection during the Oregon winter. Initial monitoring results showed rather poor performance of only 55 BTU/deghr. An improved heat exchanger installed after the first month of testing showed a marked improvement of 295 BTU/deghr, approximately the performance observed on the heat exchanger at the Philadelphia site. The externally mounted heat exchanger is vulnerable to failure due to air bubbles lodged in its line, and its performance could be compromised due to its location relative to the thermal gradients inside the solar

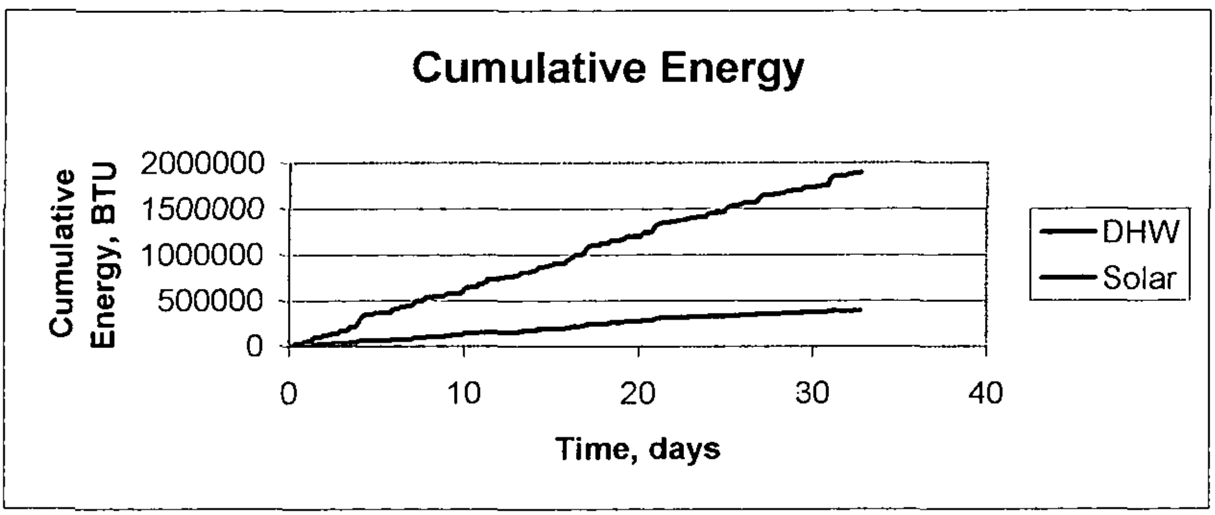
storage tank. Further monitoring during sunnier weather will confirm the long term performance expectation for this configuration.

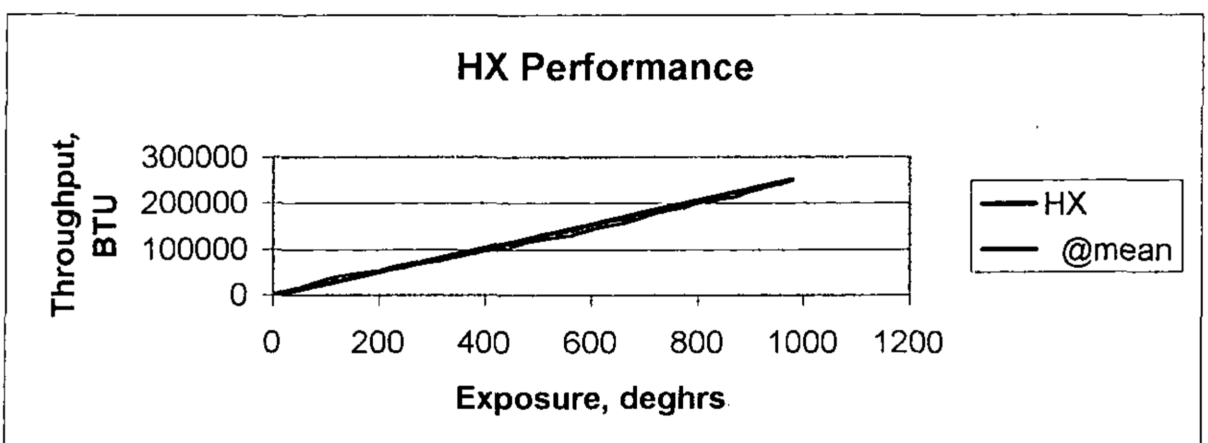
6. At both sites – Energy delivered to the solar storage tank is calculated using a solar loop flow rate estimated from measurements of the PV voltage at the solar pump. Theoretically, this voltage will correspond to a flow rate unique to the system. The one to one correspondence of the flow rate to the PV voltage is derived by correlating the monitored PV voltage to the manually read flow rate observed at the same time on a visual flow meter which is a permanent part of the solar installation. This correlation is referred to here as the PV pump calibration. At both sites this pump calibration was attempted during or shortly after the monitoring installation, but the low winter sun limited the range of the calibration. A re-calibration will be done during the spring. This re-calibration can be applied after the fact to the already existing monitoring data. The re-calibration will only effect the solar tank loss measurements and the heat exchanger measurements, and it is not expected to change these measurements by much.

SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont2a.xls

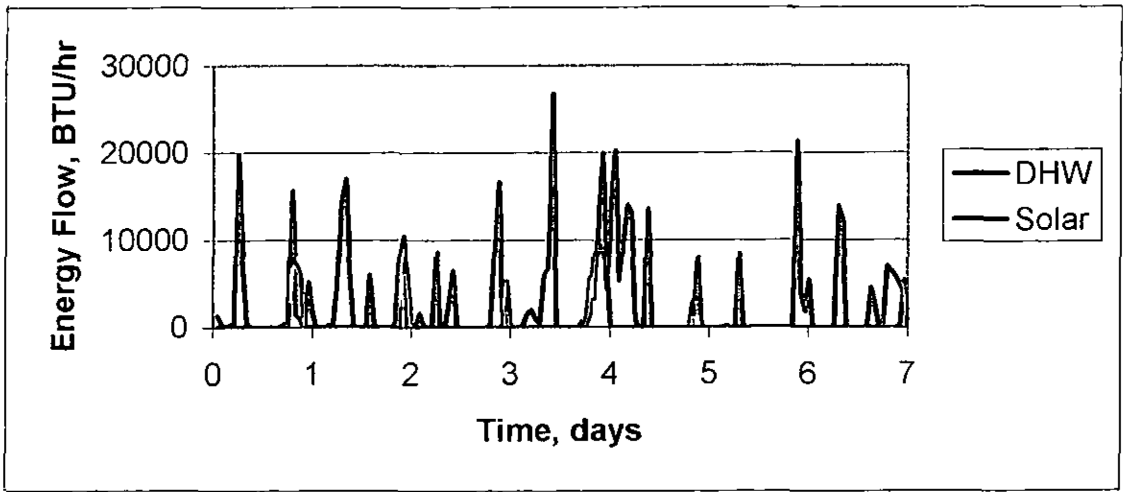
Start date	month	day	hour
	12	29	17
	jan		
Duration		32.71	days
Mean Inlet Temp		50.3	deg F
Mean Outlet Temp		113.9	deg F
Mean DHW usage		109.6	gal/day
Mean DHW BTU/day		58,075	BTU/day
Mean Solar BTU/day		11,996	BTU/day
Solar Contribution		21%	
HX Performance		259	BTU/deghr
DHW Tank Factor		0.84	
Solar Tank Factor		0.99	

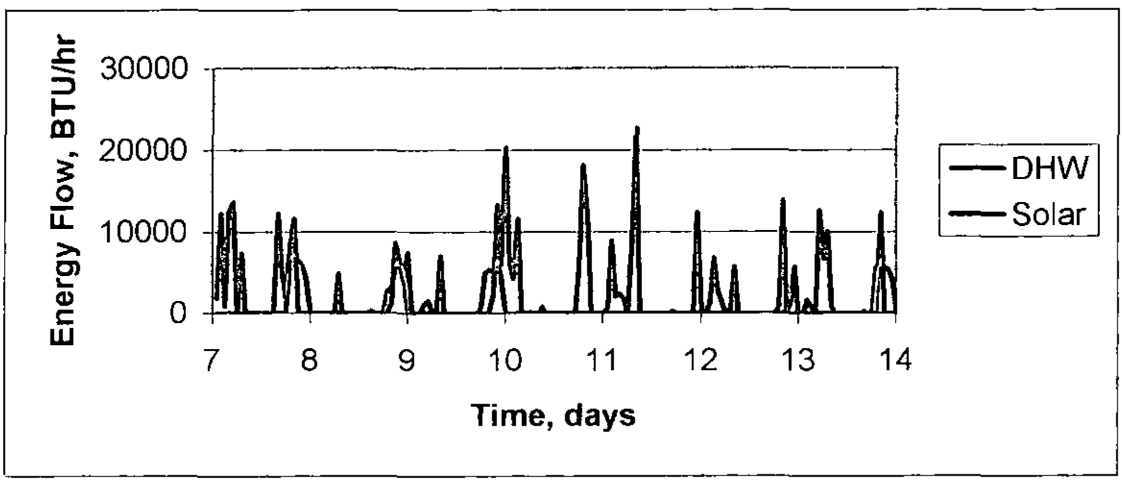


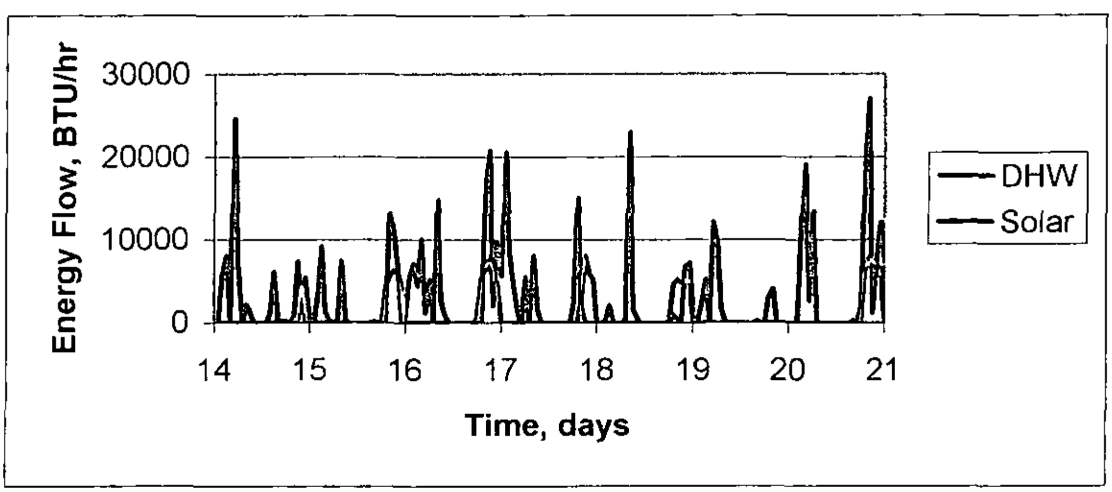


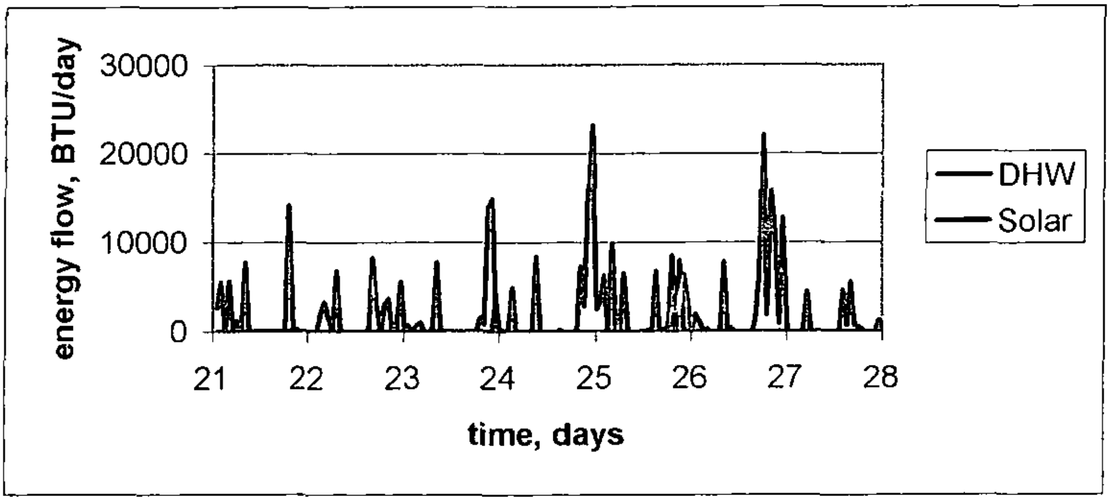


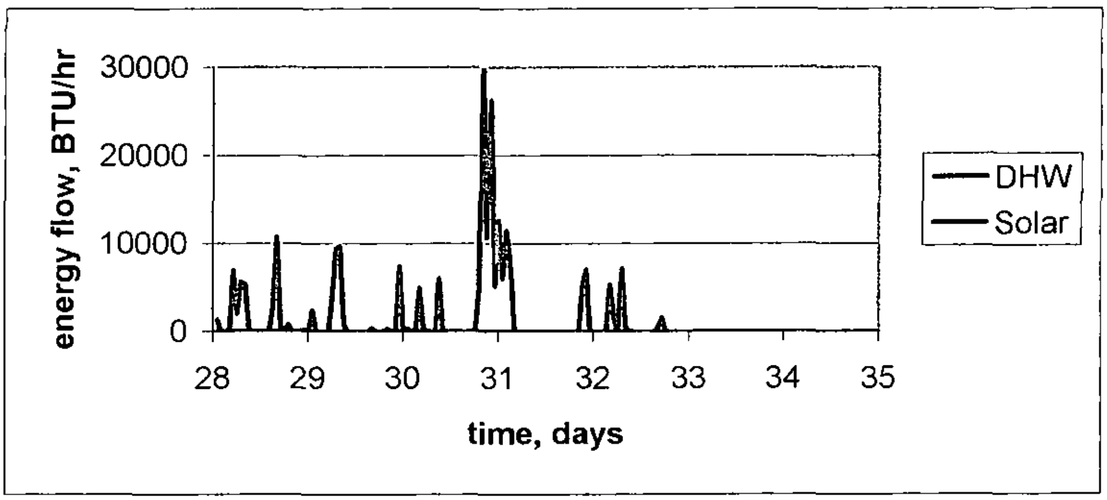
DAILY ENERGY FLOWS

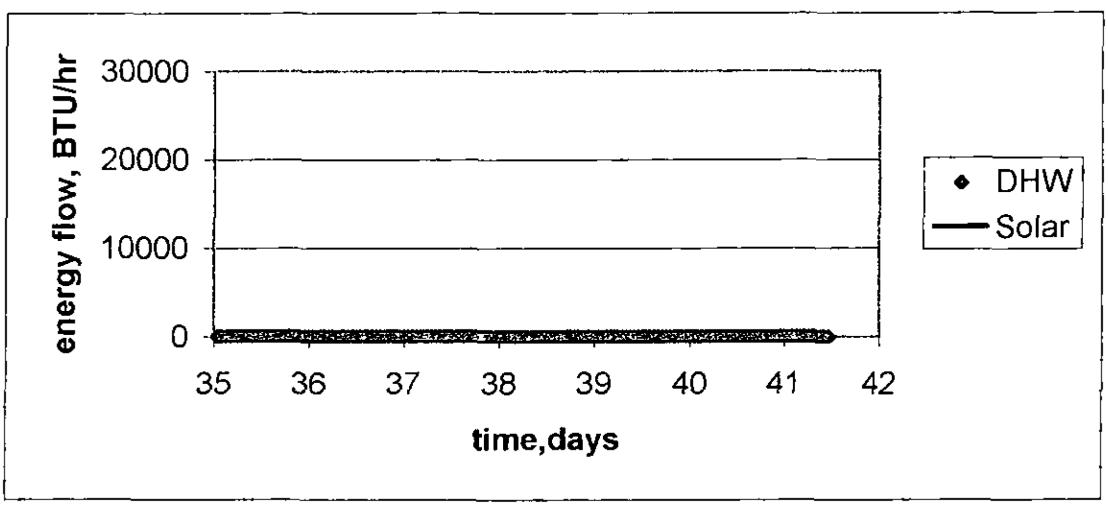







energy flow, BTU/day
30000
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar

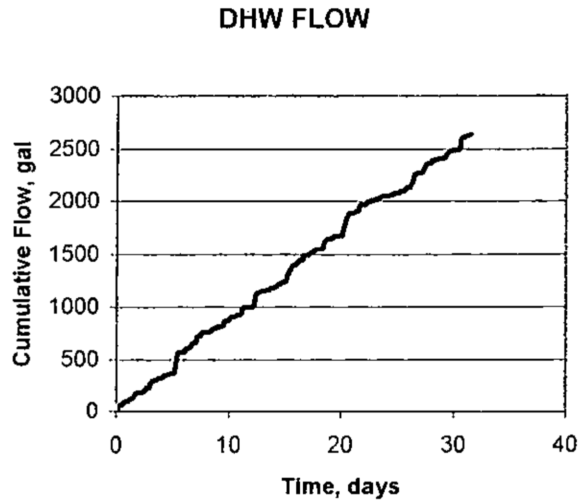

energy flow, BTU/hr
30000
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar

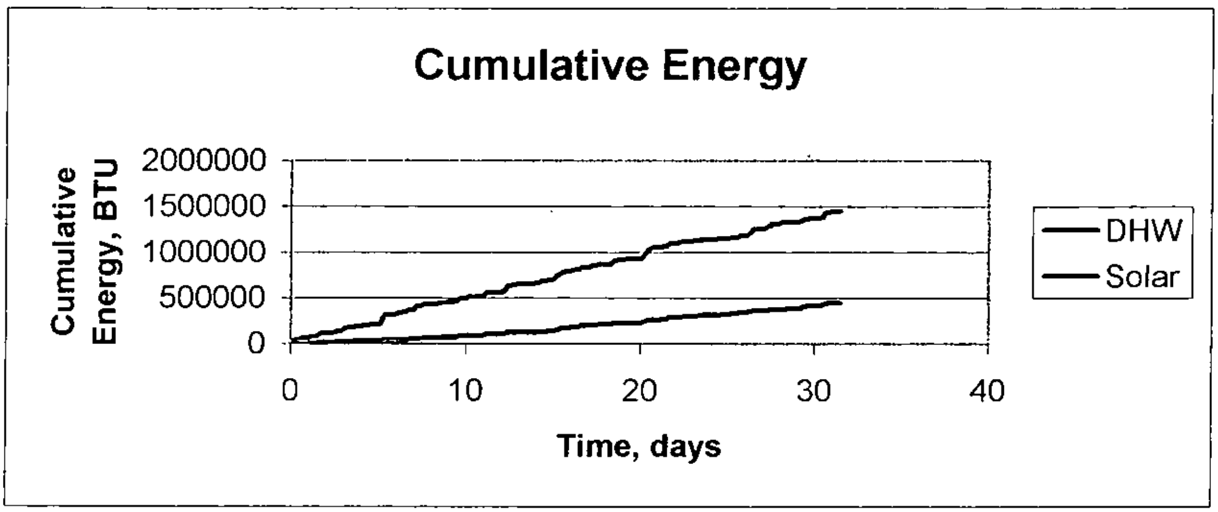

energy flow, BTU/hr
30000
20000
10000
0
35
36
37
38
39
40
41
42
time,days
DHW
Solar

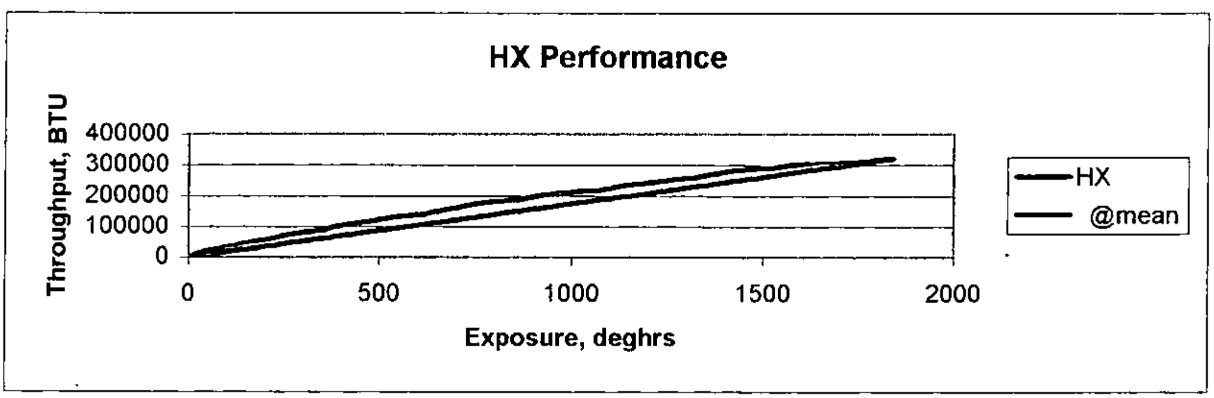
SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont3a.xls

Start date	month	day	hour
	1	31	10

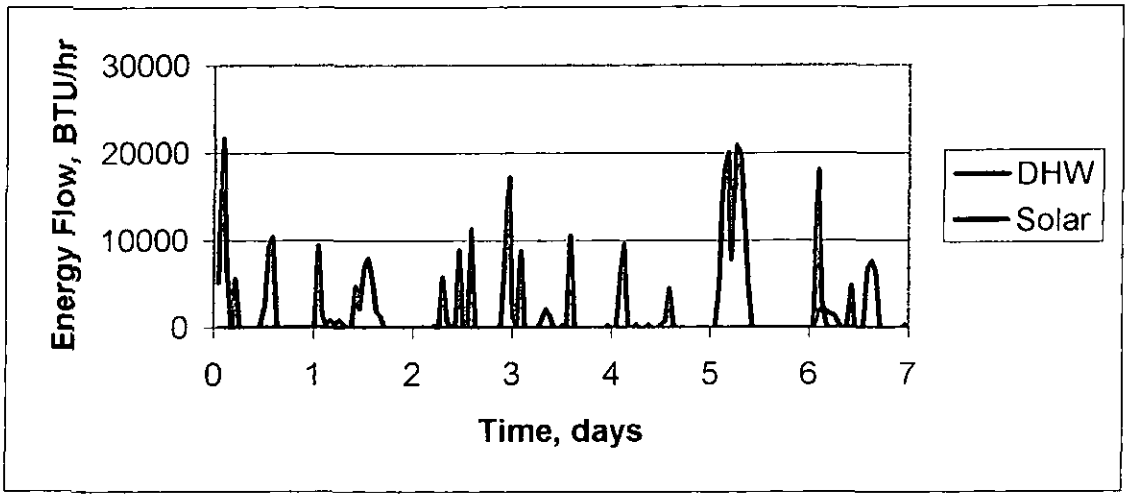
Month	**Feb**	
Duration	31.46	days
Mean Inlet Temp	48.6	deg F
Mean Outlet Temp	114.6	deg F
Mean DHW usage	84.3	gal/day
Mean DHW BTU/day	46,392	BTU/day
Mean Solar BTU/day	14,343	BTU/day
Solar Contribution	31%	
HX Performance	175	BTU/deghr
DHW tank factor	0.82	
Solar tank factor	0.92	

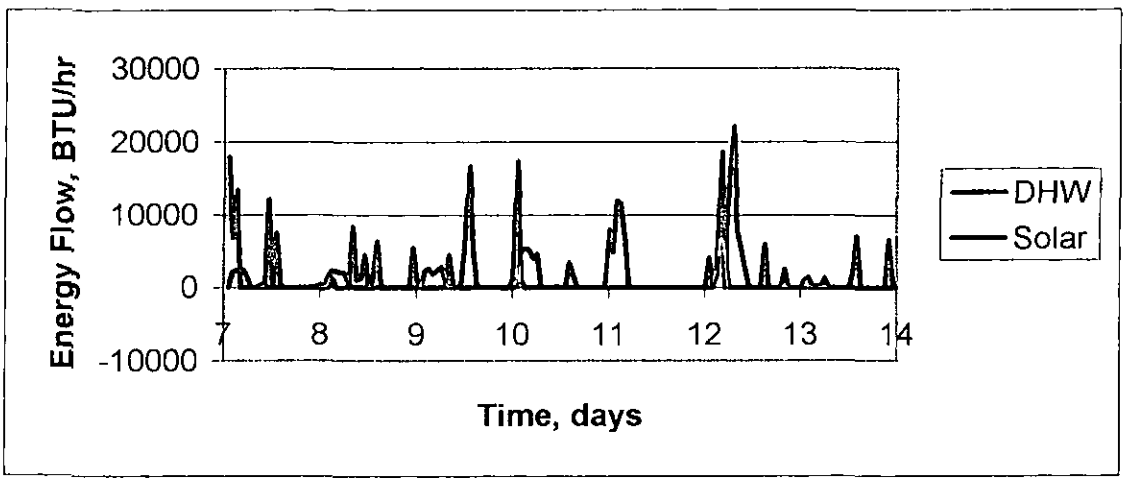


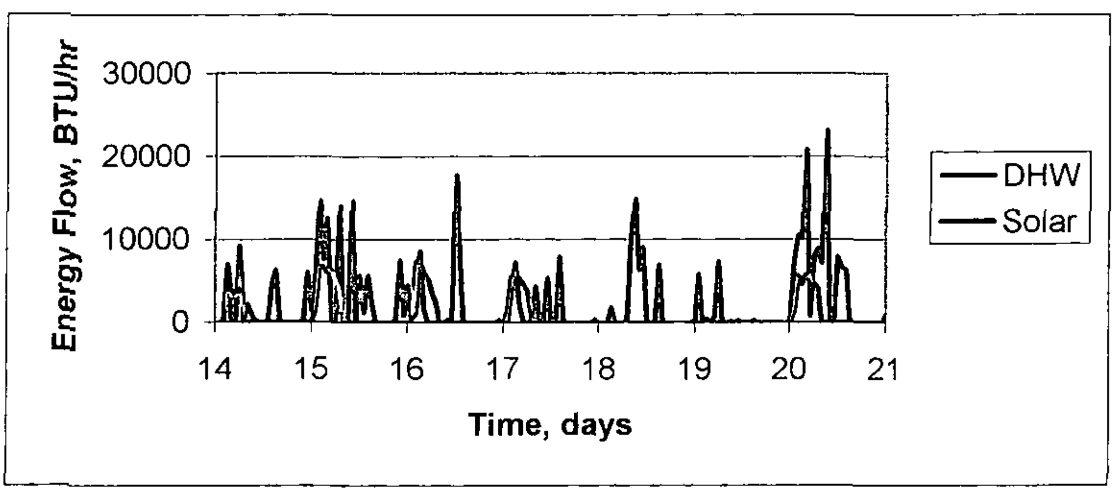


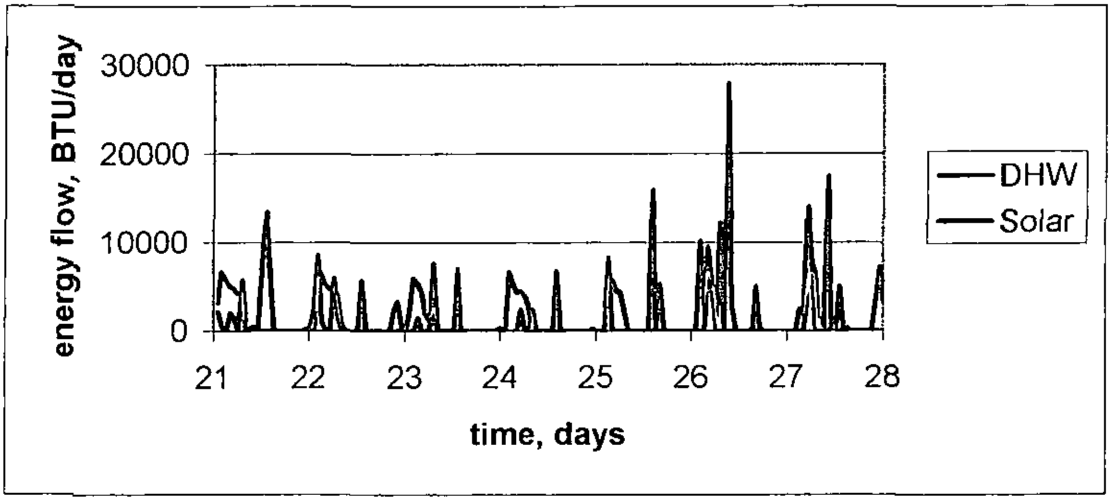


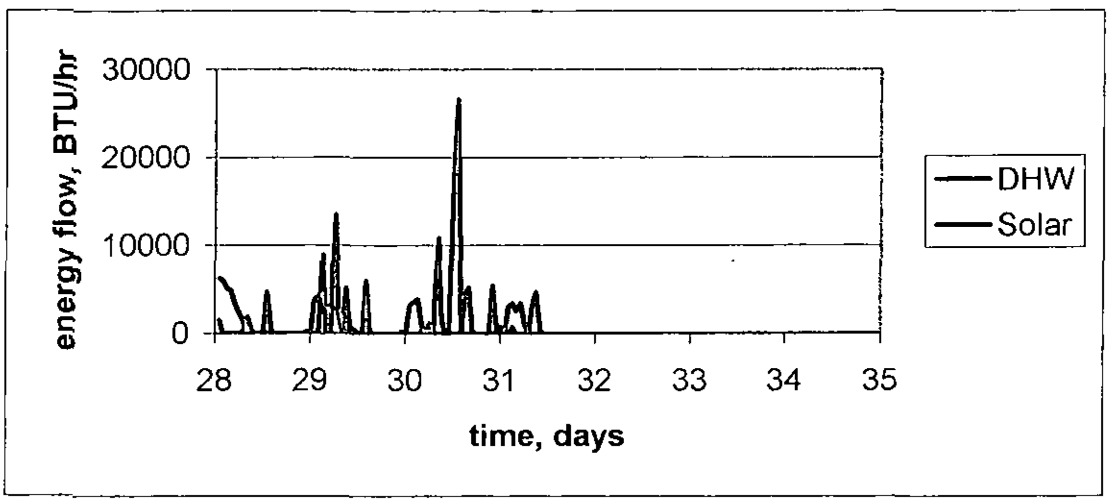
DAILY ENERGY FLOWS

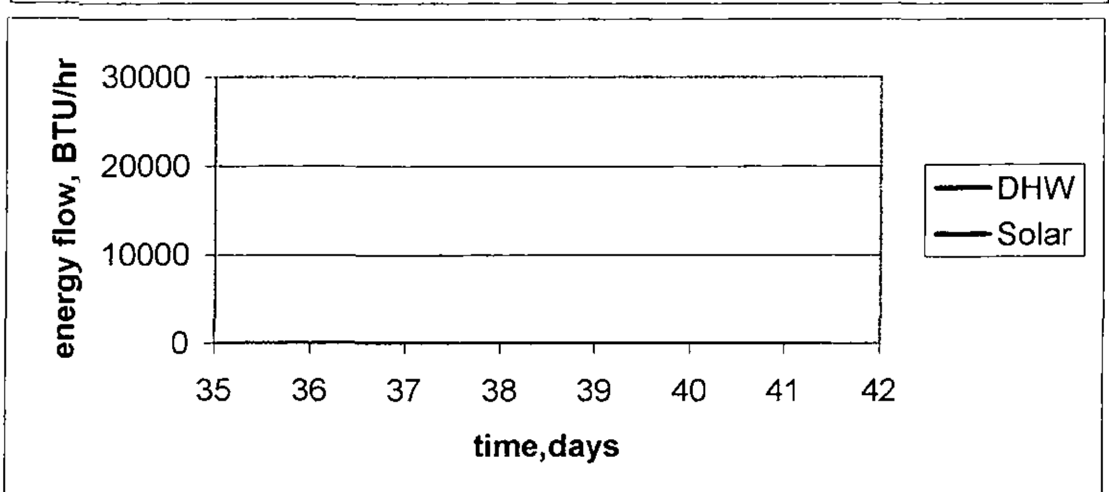







energy flow, BTU/day
30000
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar


energy flow, BTU/hr
30000
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar

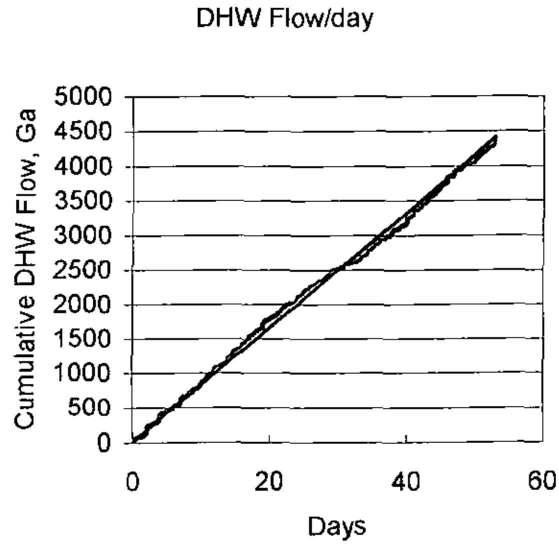

energy flow, BTU/hr
30000
20000
10000
0
35
36
37
38
39
40
41
42
time,days
DHW
Solar

SOLAR DHW SYSTEM MONITORING SUMMARY

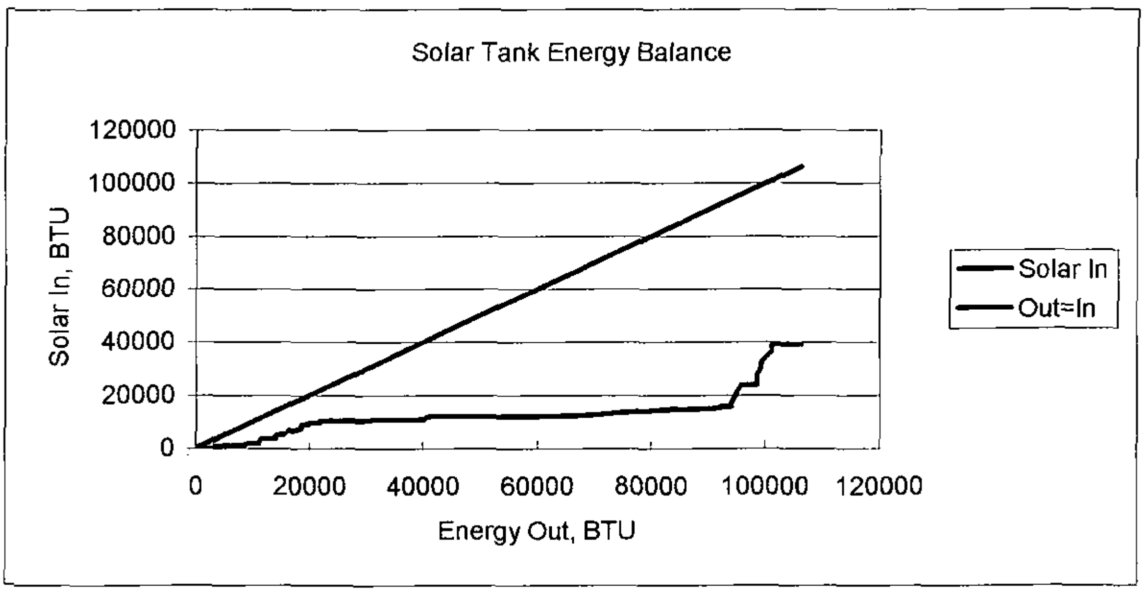
System: DHW1- lemer3.xls

Monitoring Period: 8Dec 1999 to 30 Jan 2000

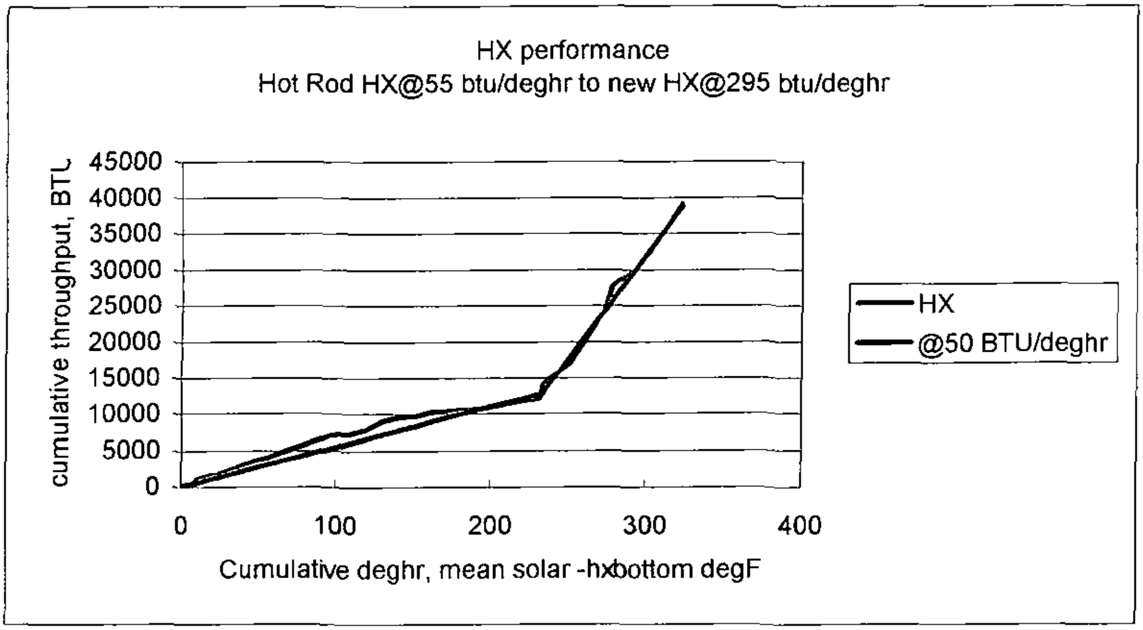
Month	*jan*
Duration	52.9 days
Mean Inlet Temp	48.4 deg F
Mean Outlet Temp	57.4 deg F
Mean DHW usage	83.5 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	1999 BTU/day
Solar Contribution	not monitored
HX Performance	290 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	2.70



DHW flow is approximately constant at 83 gallons/day



Solar input is almost insignificant for most of the monitoring period. The solar tank is gaining energy from the warm surroundings which are about 10 deg warmer than the incoming water. This situation causes the solar tank factor to be greater than 1. Typically this factor will be in the range of .7-.95.



There is a noticable change in HX performance with the installation of the replacement heat exchanger. The pump flow vs voltage should be measured again with the new HX to compensate for a different flow resistance in the new HX.

Monitoring Report #4, May 4, 2000

Solar Domestic Hot Water Heater
Location: at one Philadelphia site and at one Oregon site
Time: 28 February 2000-03 May 2000
Data Files: pont4a.xls, pont5a.xls, lemer4.xls, lemer5.xls, lemer6.xls

Summary – This monitoring for the winter months of March and April shows the solar water heating system with increasing output. The hot water usage at the test sites of 85 gallons/day is typical, though deviations from this average are evident in short bursts of extra activity or vacations. The mean hot water temperature of 115 deg F is somewhat lower than typical and may be due to the lockout of the electric element during peak periods. There is no evidence of significant or unusual thermal losses from either the solar tank or the DHW tank. The heat exchanger, which is expected to be one of the best available, is showing good performance. Flow data was not available for March at the Philadelphia site due to a loose connection, which has since been restored. Overall, the solar contribution for April was 47%.

A second site near Eugene Oregon was monitored to verify and test the monitoring approach and to examine a potential cost saving option involving an external heat exchanger and an inexpensive and smaller solar storage tank. This monitoring showed that the replacement heat exchanger is performing consistently as the solar yield increases. However the results are somewhat biased because of the use until the revised PV pump calibration can be done.

Monitoring at both sites still awaits sunnier weather when a precise PV pump calibration can be done. This improved calibration will applied after the fact to the monitored data. It is not expected to alter the summary results.

A specific review of the solar hot water heater performance is afforded by the included graphs and summary data. With respect to the summary data and graphic presentations, the following variable definitions apply:
Mean Inlet Temp – Mean temperature of the water as it enters the hot water heating system, deg F.
Mean Outlet Temp – Mean temperature of the hot water exiting the hot water heating tank, deg F.
Mean DHW Usage – Mean daily flow of water through the hot water heating system, gallons/day. A graph titled "DHW Flow" shows the cumulative flow of water through the hot water heating system during the monthly monitoring period. This graph will show a straight sloping line if the usage has been constant from day to day. A noticeable curve or angle in this graph indicates a change in hot water usage behavior.
Mean DHW BTU/day – Mean daily energy associated used to heat water. This is the total energy used to heat the hot water, including the solar energy contribution. The graph titled "Cumulative Energy" shows the cumulative energy used to heat water throughout the monthly monitoring period. This blue line on this graph will be a straight sloping line

if the hot water heating energy has been constant from day to day. A noticeable curve or angle in this graph indicates a change in the operation of the hot water heating system.
Mean Solar BTU/day – Mean daily solar contribution toward hot water heating energy. Usually the solar contribution will vary significantly from day to day with the solar conditions. The graph titled "Cumulative energy" includes a red line to show the solar contribution to the hot water heating energy. A straight sloping line here indicates consistent day to day performance by the solar water heater. A noticeable curve or angle indicates a change in the operation of the solar water heating system.
Solar Contribution – This is the portion, expressed as percent, of the water heating energy load contributed by solar energy. In essence this is the bottom line of the monitoring.
HX Performance – This is a measure of the average monthly performance of the heat exchanger component of the solar water heating system. It is expressed in BTU/deghr to provide a relative measure of the flow of thermal energy through the heat exchanger in response to a temperature difference between the fluid in the solar loop and the temperature at the bottom of the tank. Ideally, a heat exchanger can be quite complex to monitor because its performance will depend on many factors which are very difficult to monitor, such as natural convection or thermal stratification in the storage tank. Rigorous monitoring of heat exchanger performance is well beyond the scope of this project, due to the needs for complex monitoring and modeling. But some form of comparative heat exchanger monitoring is necessary to validate the proper operation of the system from month to month, and to provide a basis for comparing the operation of systems with different types of heat exchangers. This HX performance parameter is readily established by simple monitoring and it will serve the needs for a comparative heat exchanger performance measurement. The red line on the graph titled "HX Performance" shows the cumulative heat exchange throughput in response to the cumulative temperature difference between the solar fluid and the tank bottom. A noticeable curve or angle in the red line indicates a change in the operation of the heat exchanger during the monthly monitoring period.
DHW Tank Factor – The DHW tank factor measures the losses from the DHW tank to the surrounding space and the connected piping. This factor is defined as the total energy withdrawn from the tank divided by the total energy input to the tank, including all energy input to the tank by the electric element. A good modern tank under typical conditions would have a factor of .93. Typical tanks have factors from .8 to .9.
Solar Tank Factor - The Solar Tank factor measures the losses from the solar tank to the surrounding space and through the connected piping. This factor is defined as the total energy withdrawn from the solar tank divided by the energy input to the solar tank. This factor will vary seasonally with the temperature of the solar tank. The principal use of this factor is to detect thermal losses at night from the solar tank to the solar collectors. Values of this factor below .8 are indicators of potential thermal loss modes.
Daily Energy Flows – The graphs titled "DAILY ENERGY FLOWS" show the the total energy drawn from the DHW system as a blue line and the total solar energy input to the system as a red line. These energy flows are expressed as BTU/hour.

Review of the summary and graphic output reveals the following:

1. At Philadelphia, DHW2 - Two winter months of monitoring under actual Philadelphia usage and site conditions shows the solar water heater producing a 47% contribution for April. A solar contribution for March is not available because the DHW flow meter was not operating due to a loose connection. This is consistent with the design expectation for this system. The solar contribution can reasonably be expected to increase significantly as the year proceeds.

2. At Philadelphia, DHW2 - The hot water usage at this installation in April was 96 gallons/day. This higher than average usage is caused by a few days of very high use which biased the average. The mean outlet temperature of 112-115 deg F is somewhat lower than would be expected from a hot water heater with a thermostat typically set at 120 deg F or higher. Partly this lower than expected outlet temperature is due to a significant use of hot water during the peak interval when the electric heating elements are disengaged. Also the hot water thermostat has not yet been restored to a higher setting from its low prior setting.

3. At Philadelphia, DHW2 - The DHW tank exhibits losses of the order of 15% which is typical for such a tank. The solar tank exhibits losses of only a few percent which is typical for this time of year. There is no indication of night losses from the solar tank to the roof mounted solar panels. The April solar tank losses were negative on the first analysis of the data. This is probably a consequence of assumed PV calibration which is too low. For data Pont 4&5 data files the pump calibration factor was changed from .8 to 1.4. The PV pump calibration will have a strong effect on the final estimates of the HX performance and the solar tank factors.

4. At Philadelphia, DHW2 - The heat exchanger shows a higher average performance factor for January/February than for March/April. Careful examination of the hourly heat exchanger performance shows that the performance is highest in the morning and diminishes throughout the day as energy is stored in the solar storage tank. This is typical for this type of heat exchanger performance measure which is referenced to the low and relatively constant temperatures at the bottom of the tank. This type of heat exchanger measure is intended to capture the broad effects of the location of the heat exchanger relative to the tank and the size of the heat exchanger relative to the size of the tank. Heat exchanger operation observed so far shows good operation as expected. The heat exchanger is a major design consideration in the system and it can have a significant effect on the efficiency of the system. Following the heat exchanger performance month to month and from system type to system type is expected to be valuable in confirming or modifying system design decisions. The final assessment of HX performance will need to be done at the conclusion of the monitoring when a refined PV pump calibration can be used in all files.

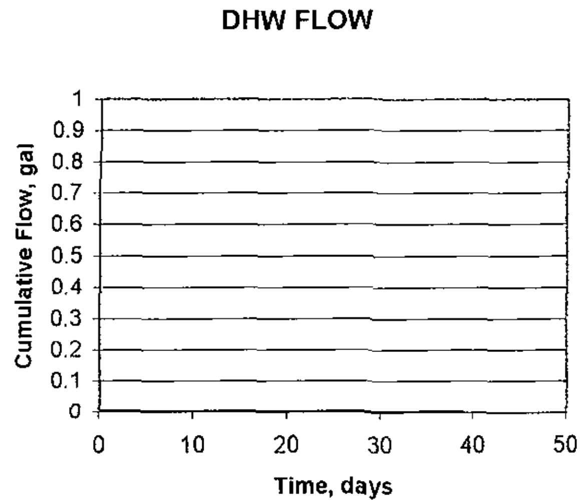
5. At Eugene, DHW1 – Monitoring at this site is limited to the solar storage tank and the heat exchanger. This site shows a DHW use of 85 gallons/day, which is reasonable for this size family. Solar collection has increased significantly during March and April. The heat exchanger performance appears to be consistent as the solar collection

increases. The solar tank factor however is decreasing with the increased solar collection, indicating a possible night thermal loss mode. Further monitoring during sunnier weather and careful calibration of the PV pump will confirm the long term performance expectation for this configuration relative to the Philadelphia sites.

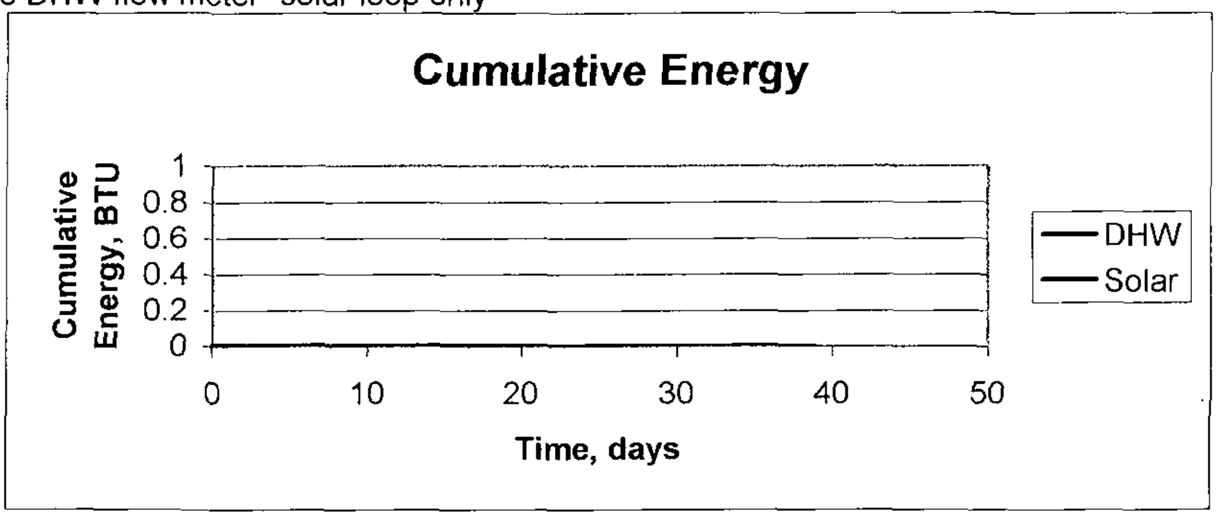
6. At both sites – Energy delivered to the solar storage tank is calculated using a solar loop flow rate estimated from measurements of the PV voltage at the solar pump. Theoretically, this voltage will correspond to a flow rate unique to the system. The one to one correspondence of the flow rate to the PV voltage is derived by correlating the monitored PV voltage to the manually read flow rate observed at the same time on a visual flow meter which is a permanent part of the solar installation. This correlation is referred to here as the PV pump calibration. At both sites this pump calibration was attempted during or shortly after the monitoring installation, but the low winter sun limited the range of the calibration. A re-calibration will be done in May 2000. This re-calibration will be applied after the fact to the already existing monitoring data. The re-calibration is essential to accurate estimates of solar tank loss and heat exchanger performance.

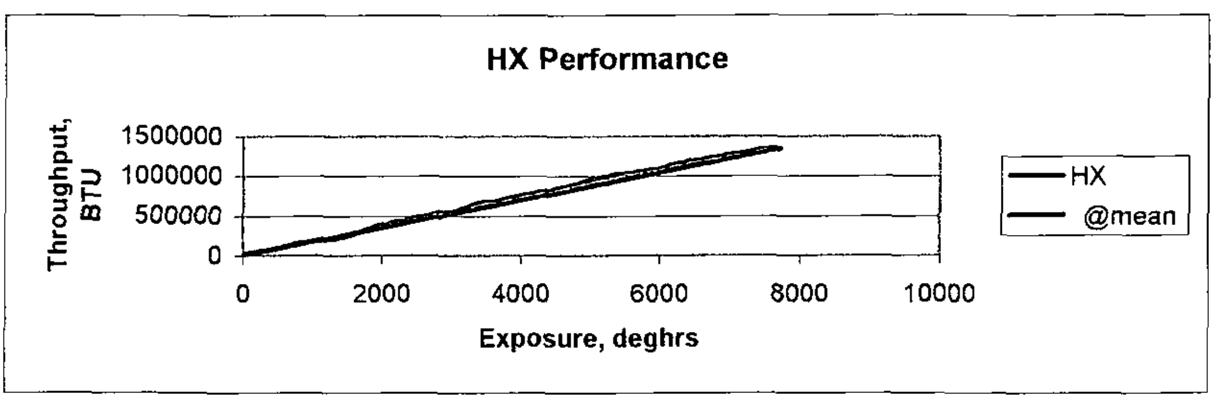
SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont4a.xls

Start date	month	day	hour
	0	0	34761
Month	apr		
Duration	38.92	days	
Mean Inlet Temp	#DIV/0!	deg F	
Mean Outlet Temp	#DIV/0!	deg F	
Mean DHW usage	0.0	gal/day	
Mean DHW BTU/day	0	BTU/day	
Mean Solar BTU/day	0	BTU/day	
Solar Contribution	#DIV/0!		
HX Performance	175	BTU/deghr	
DHW tank factor	0.00		
Solar tank factor	0.00		

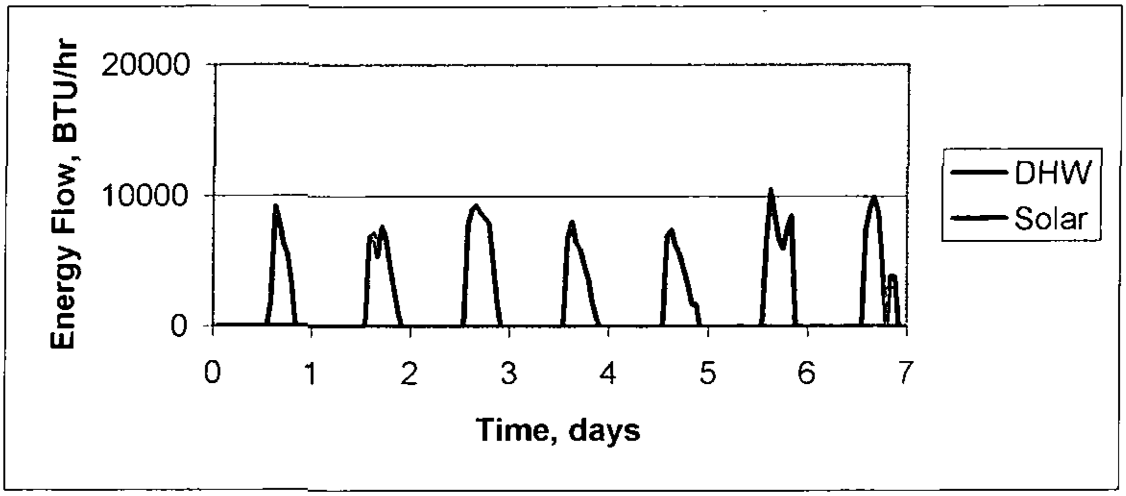


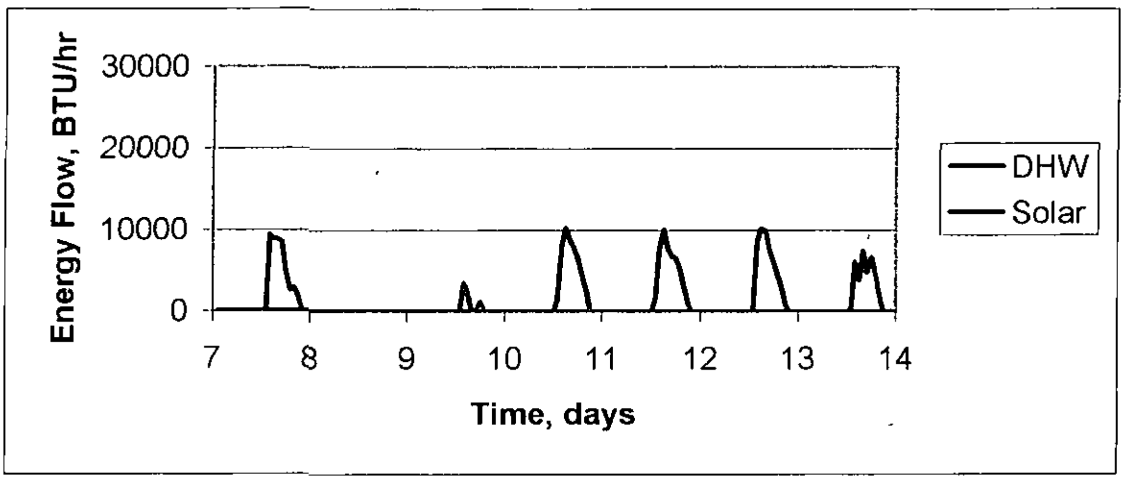
note: pump calibration changed from .8 to 1.
no DHW flow meter- solar loop only

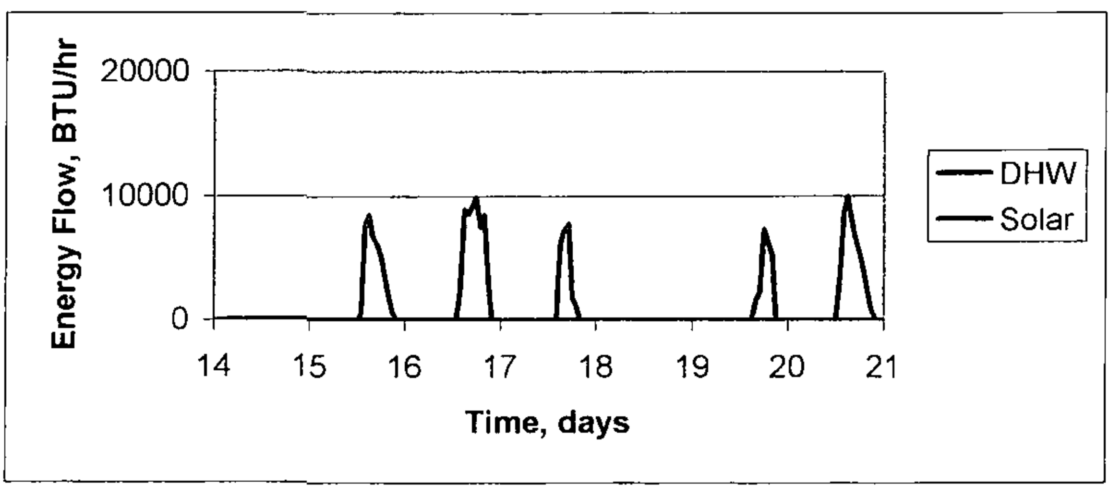


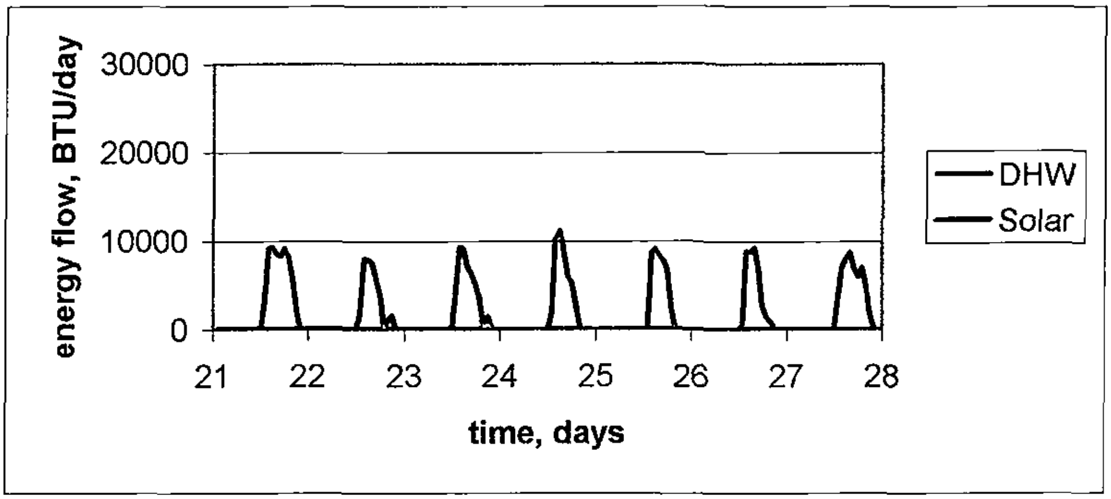


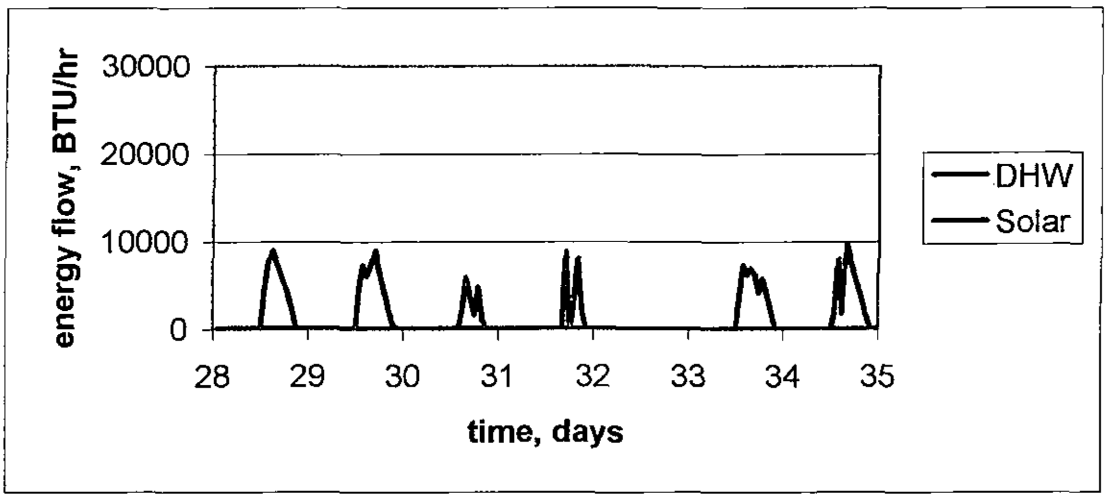
DAILY ENERGY FLOWS

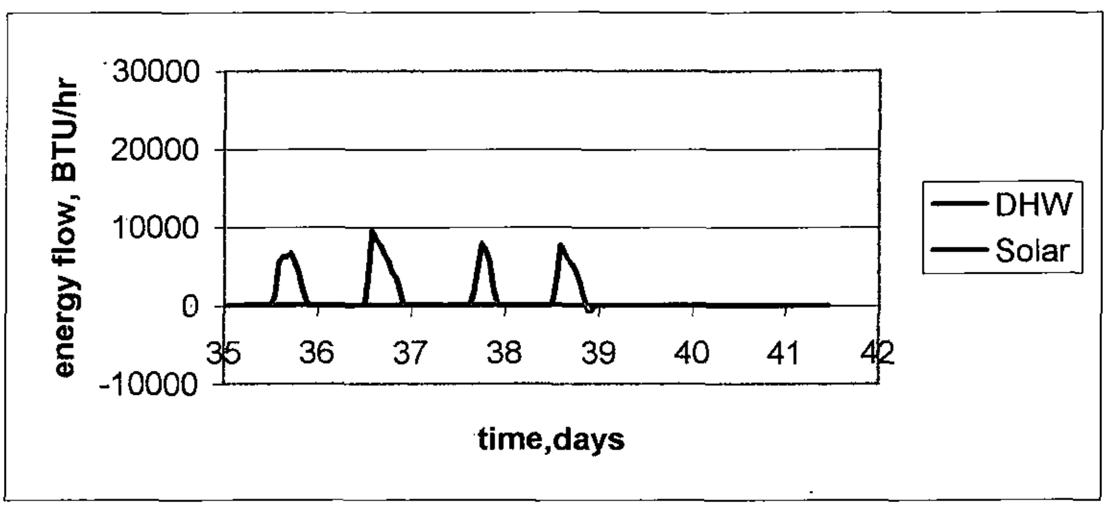







energy flow, BTU/day
30000
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar

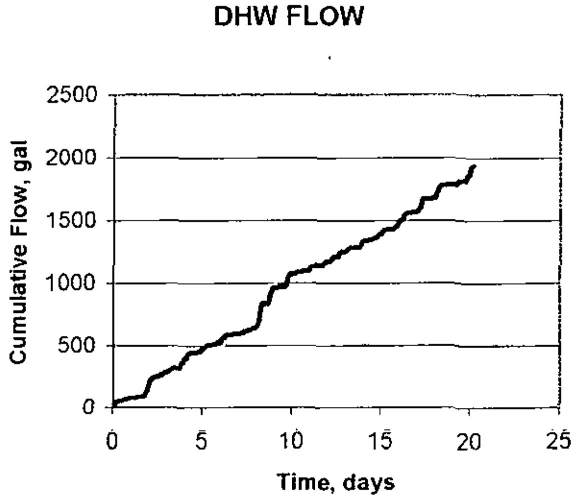

energy flow, BTU/hr
30000
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar


energy flow, BTU/hr
30000
20000
10000
0
-10000
35
36
37
38
39
40
41
42
time,days
DHW
Solar

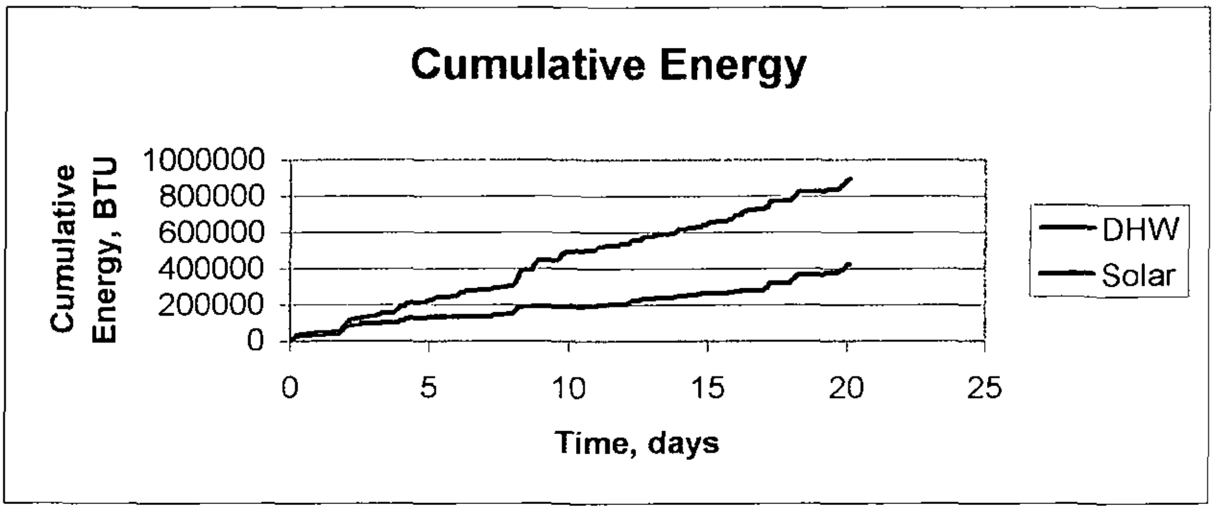
SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont5a.xls

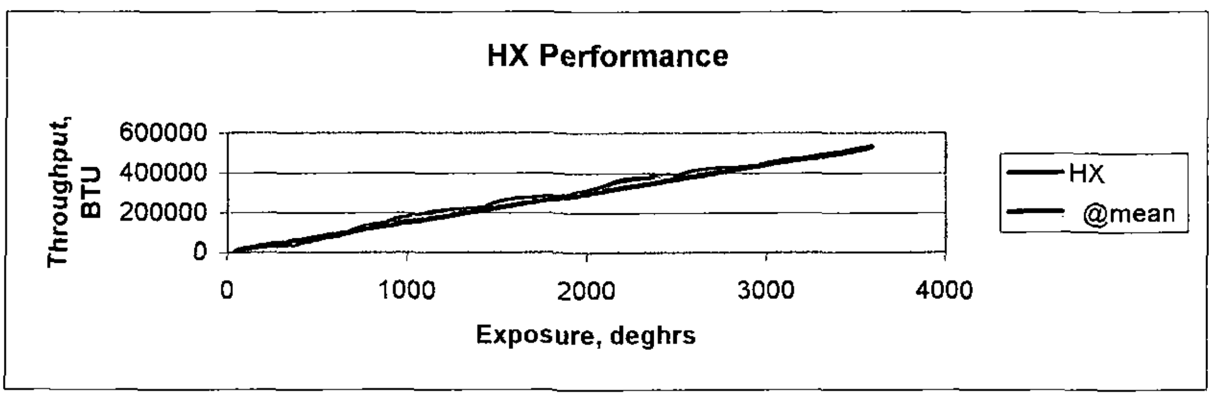
Start date	month	day	hour
	4	13	17

Month	apr	
Duration	20.13	days
Mean Inlet Temp	58.3	deg F
Mean Outlet Temp	113.8	deg F
Mean DHW usage	96.5	gal/day
Mean DHW BTU/day	44,660	BTU/day
Mean Solar BTU/day	21,182	BTU/day
Solar Contribution	47%	
HX Performance	148	BTU/deghr
DHW tank factor	0.83	
Solar tank factor	0.71	

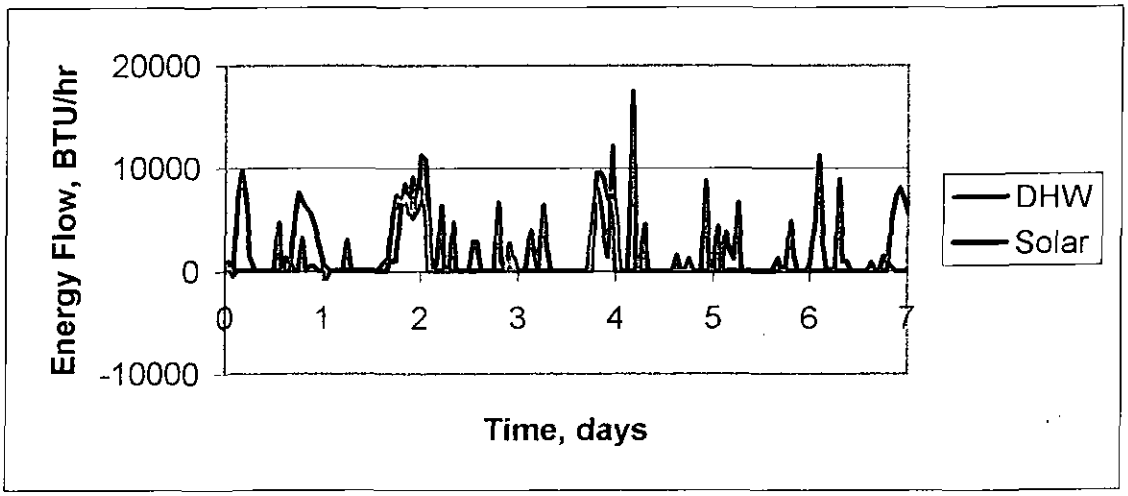


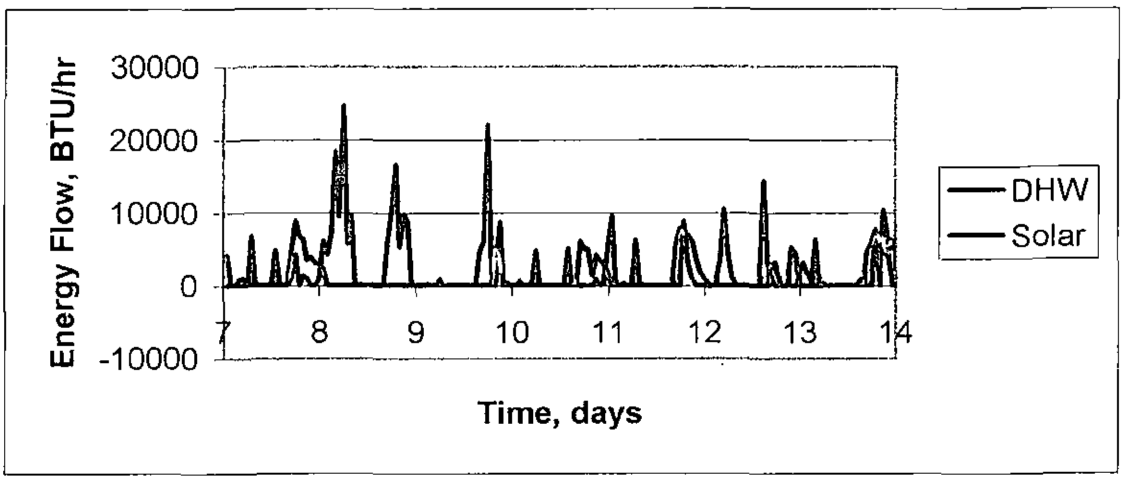
note: pump calibration changed from .8 to 1.

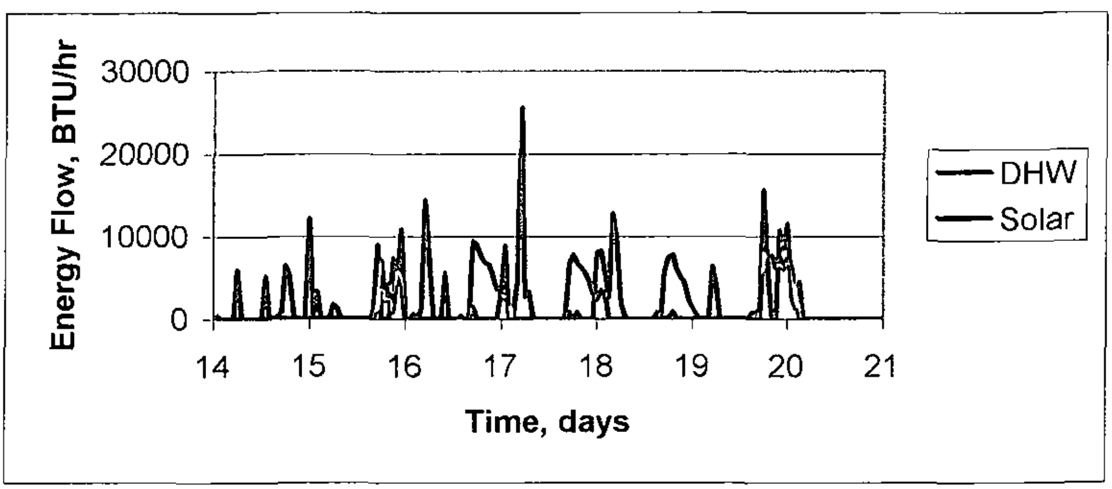


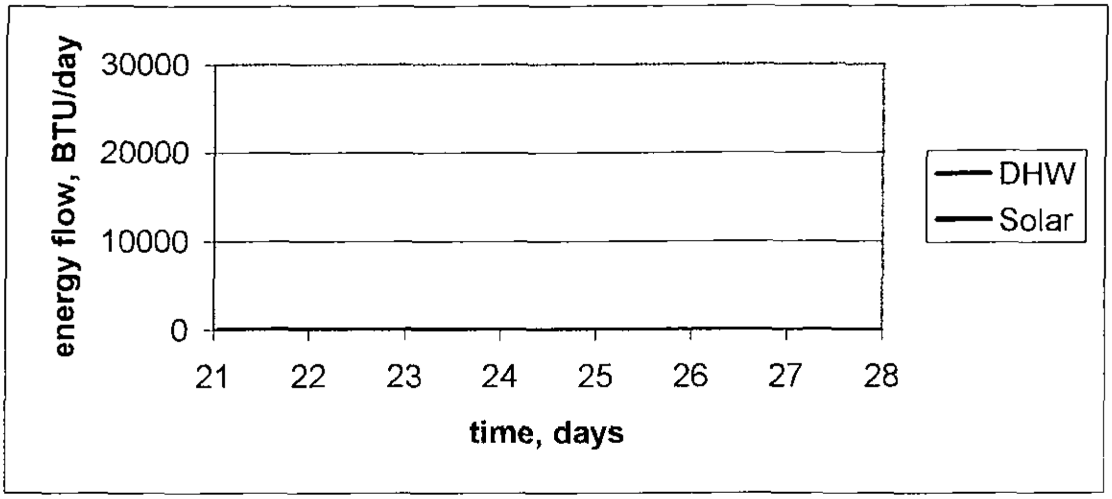


DAILY ENERGY FLOWS

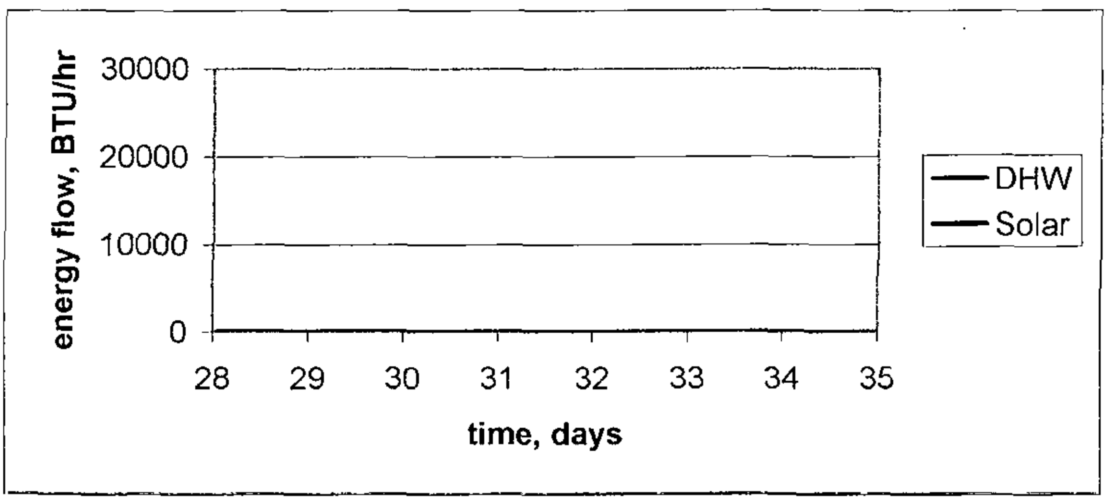




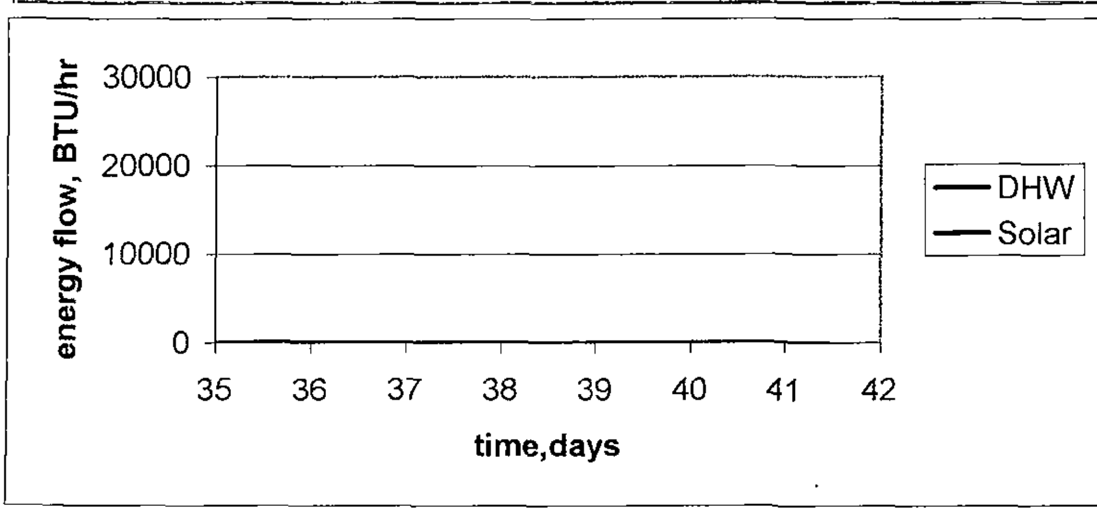




energy flow, BTU/day
30000
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar



energy flow, BTU/hr
30000
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar



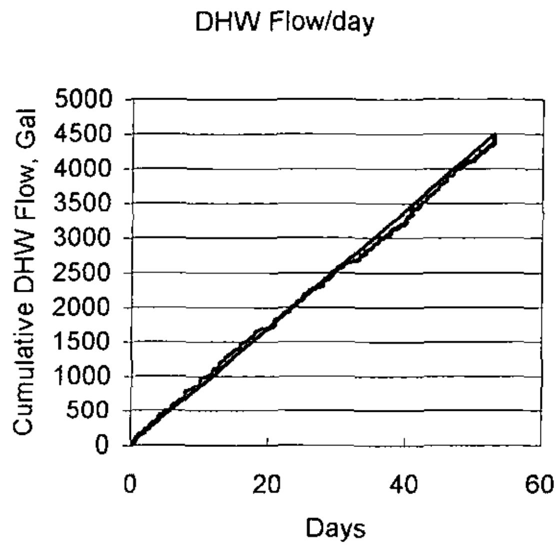
energy flow, BTU/hr
30000
20000
10000
0
35
36
37
38
39
40
41
42
time,days
DHW
Solar

SOLAR DHW SYSTEM MONITORING SUMMARY

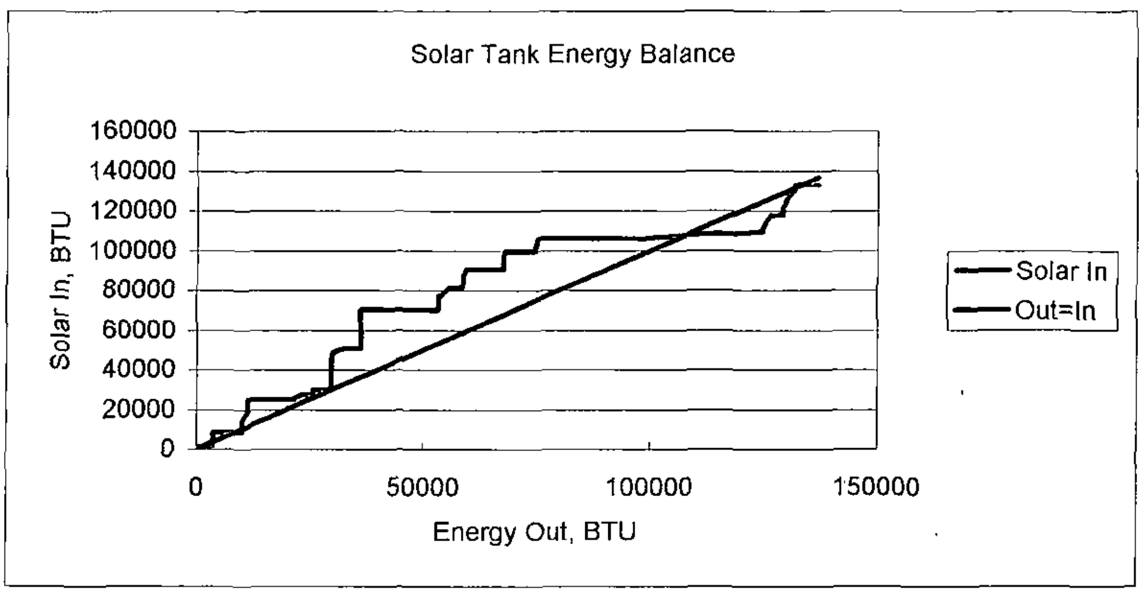
System: DHW1- lemer4.xls

Monitoring Period: 31 Jan 2000 to 29 Feb 2000

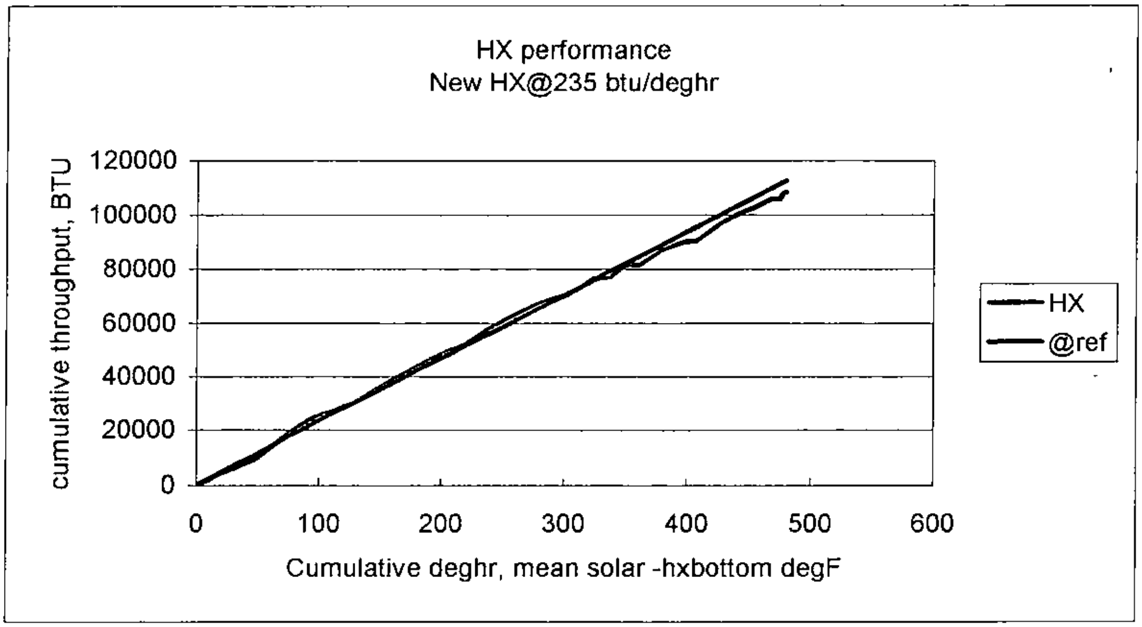
Month	feb
Duration	30.1 days
Mean Inlet Temp	57.2 deg F
Mean Outlet Temp	60.8 deg F
Mean DHW usage	85.1 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	2603 BTU/day
Solar Contribution	not monitored
HX Performance	235 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.74



DHW flow is approximately constant at 85 gallons/day



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. A brief period of limited solar gain and a cooler tank shows reduced tank losses.



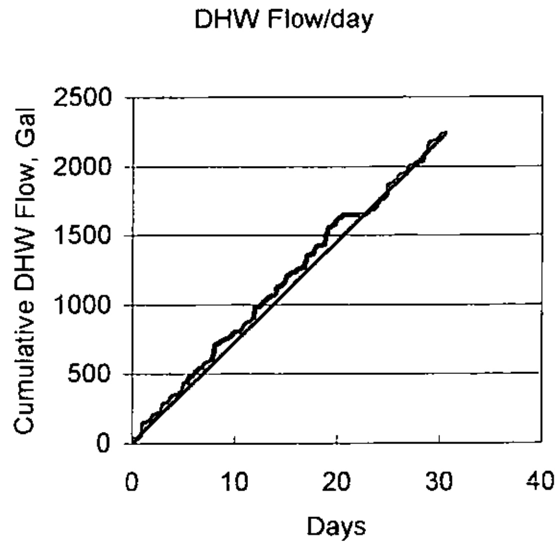
The HX performance is consistent with the improved performance of the replacement heat exchanger.

SOLAR DHW SYSTEM MONITORING SUMMARY

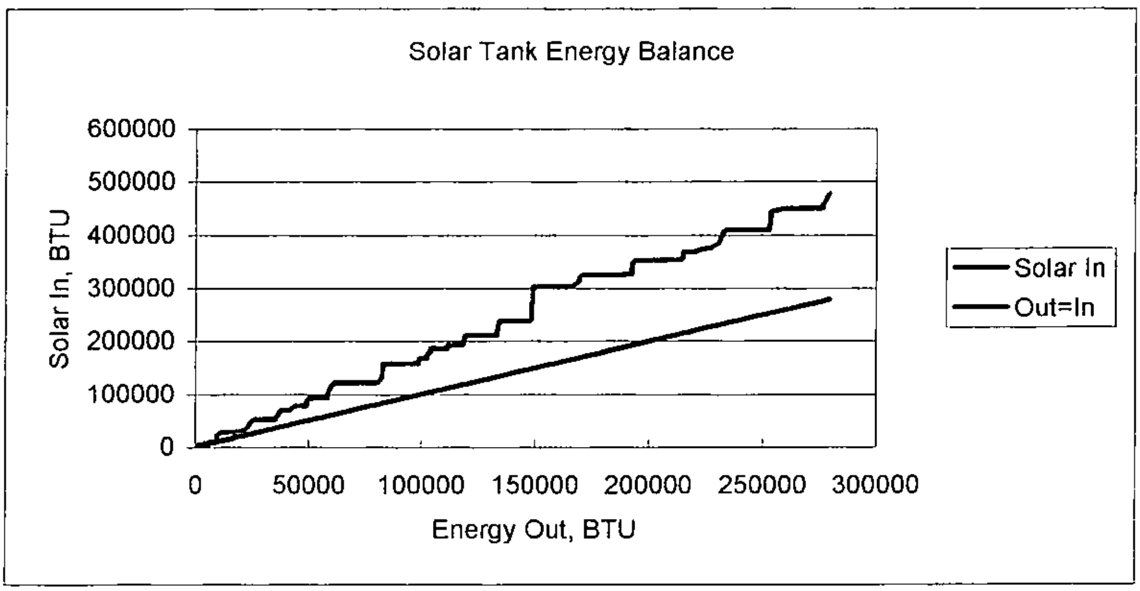
System: DHW1- lemer5.xls

Monitoring Period: 1 Mar 2000 to 31 Mar 2000

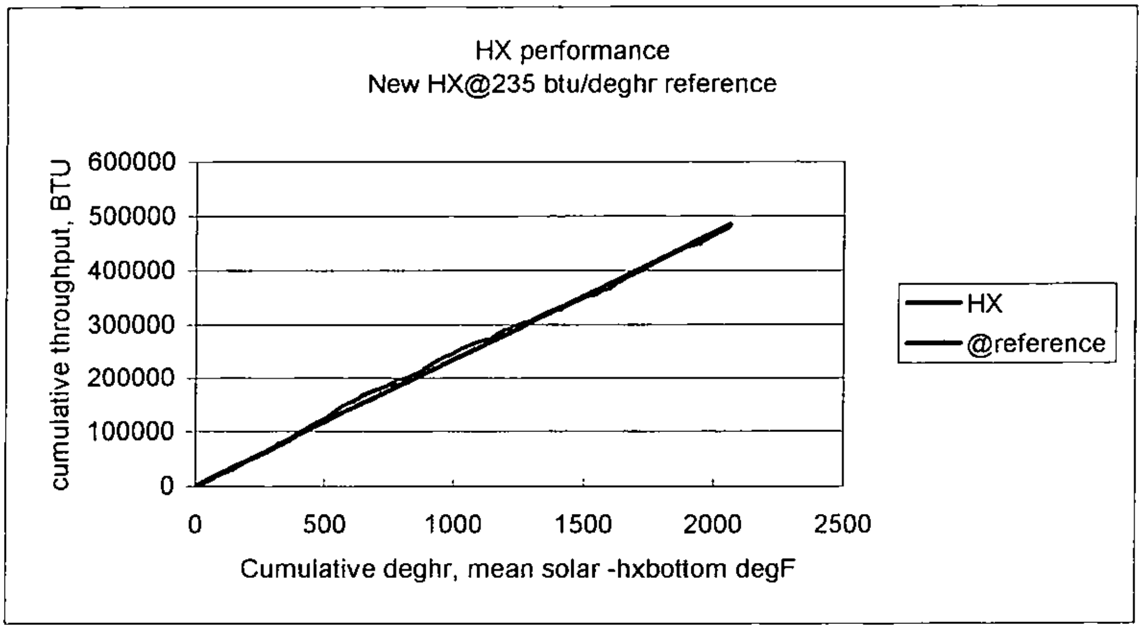
Month	mar
Duration	30.5 days
Mean Inlet Temp	57.7 deg F
Mean Outlet Temp	72.7 deg F
Mean DHW usage	73.2 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	9152 BTU/day
Solar Contribution	not monitored
HX Performance	235 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.58



DHW flow is approximately constant at 85 gallons/day, but mean flow is less because of inactivity for several days at day 20.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. These results are also attributable to the changed solar pump flow rate. The solar pump flow rate needs to be recalibrated.



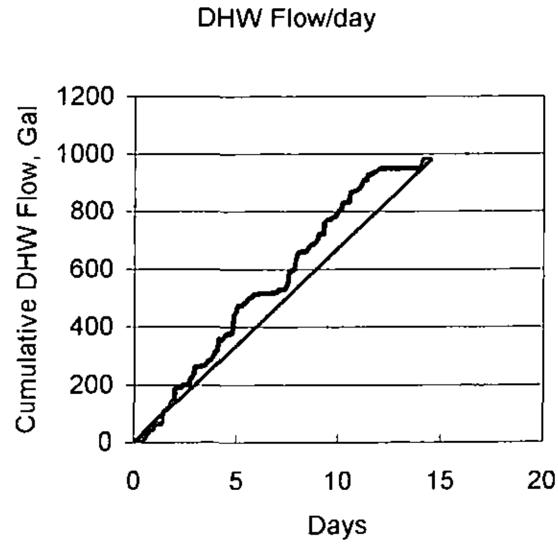
The HX performance is consistent with the improved performance of the replacement heat exchanger.

SOLAR DHW SYSTEM MONITORING SUMMARY

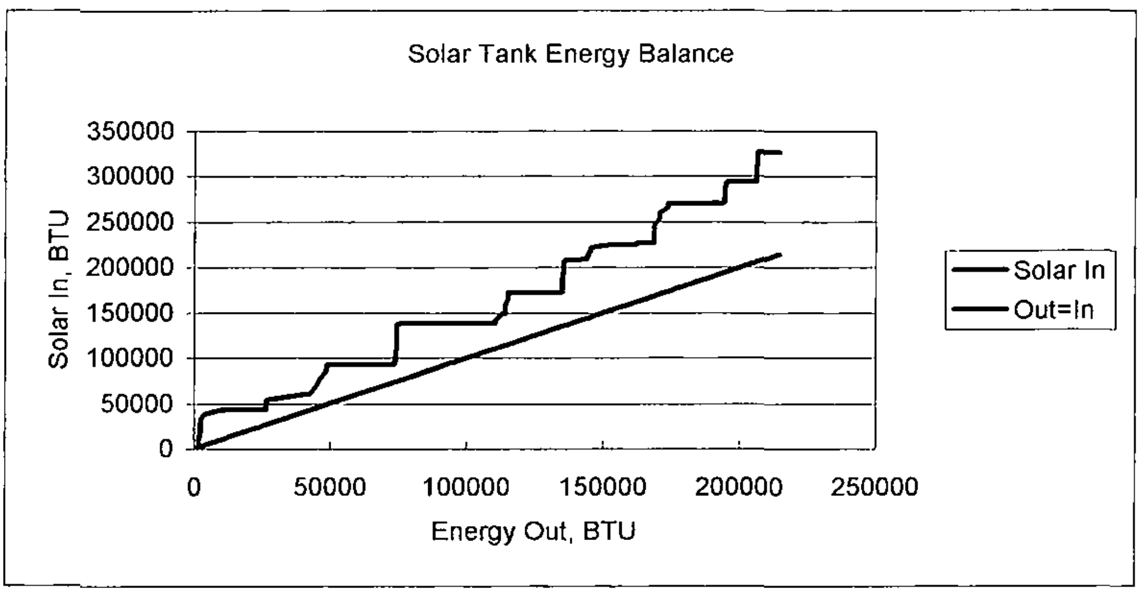
System: DHW1- lemer6.xls

Monitoring Period: 1 Apr 2000 to 16 Apr 2000

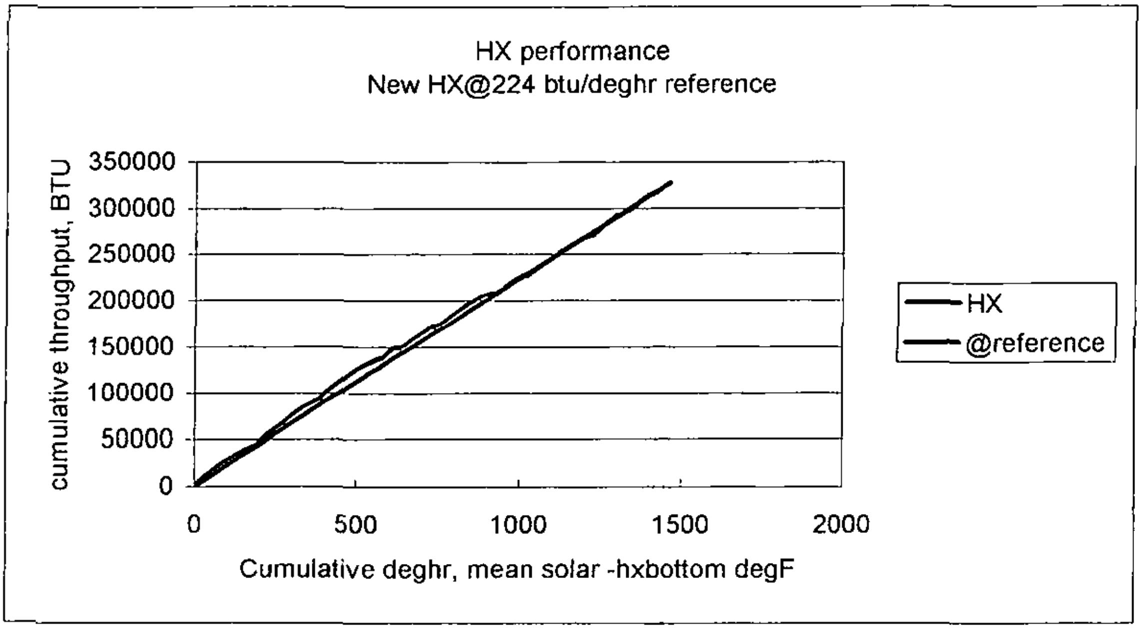
Month	apr
Duration	14.5 days
Mean Inlet Temp	58.4 deg F
Mean Outlet Temp	84.6 deg F
Mean DHW usage	67.6 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	14796 BTU/day
Solar Contribution	not monitored
HX Performance	224 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.66



DHW flow is approximately constant at 85 gallons/day, but mean flow is less because of inactivity for several days at days 5-7 and 10-12.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. These results are also attributable to the changed solar pump flow rate. The solar pump flow rate needs to be recalibrated.



The HX performance is consistent with the improved performance of the replacement heat exchanger.

Monitoring Report #5, June 9, 2000

Solar Domestic Hot Water Heaters
Location: at two Philadelphia sites and at one Oregon site
Time: 3 May 2000-09 June 2000
Data Files: pont7.xls, lemer8f.xls, strelau3.xls

Summary – This monitoring for the spring month of May shows all three solar water heating systems with increasing output. The hot water usage at the test sites of 85 gallons/day is typical, though deviations from this average are evident in short bursts of extra activity or vacations. Site 3 had a mean hot water temperature of 133 deg F is somewhat higher than typical and the participants observed that the water was too hot. There is no evidence of significant or unusual thermal losses from either the solar tank or the DHW tank. The heat exchangers, are showing good performance in the range of 50-150 BTU/deg hr. Solar yield is ranges from 18,000-23000 BTU/day.

Monitoring at all sites includes a site measured PV pump calibration. This improved calibration has been applied after the fact to the monitored data. Solar yields calculated using the improved flow rates appear to understate the solar loop yields. A difference of this type could be due to errors in the temperature sensors. The temperature sensor placement and calibration at all sites will be checked.

Performance at site # 3 shows an unusual morning temperature spike, sometimes as high as 200 deg F. This could be caused by irregular pump behavior or a partial flow blockage. This situation is documented in *performance note –site 3* included below.

A specific review of the solar hot water heater performance is afforded by the included graphs and summary information taken from the monitored data. With respect to the summary information and graphic presentations, the following variable definitions apply:
Mean Inlet Temp – Mean temperature of the water as it enters the hot water heating system, deg F.
Mean Outlet Temp – Mean temperature of the hot water exiting the hot water heating tank, deg F.
Mean DHW Usage – Mean daily flow of water through the hot water heating system, gallons/day. A graph titled "DHW Flow" shows the cumulative flow of water through the hot water heating system during the monthly monitoring period. This graph will show a straight sloping line if the usage has been constant from day to day. A noticeable curve or angle in this graph indicates a change in hot water usage behavior.
Mean DHW BTU/day – Mean daily energy associated used to heat water. This is the total energy used to heat the hot water, including the solar energy contribution. The graph titled "Cumulative Energy" shows the cumulative energy used to heat water throughout the monthly monitoring period. This blue line on this graph will be a straight sloping line

if the hot water heating energy has been constant from day to day. A noticeable curve or angle in this graph indicates a change in the operation of the hot water heating system.

Mean Solar BTU/day – Mean daily solar contribution toward hot water heating energy. Usually the solar contribution will vary significantly from day to day with the solar conditions. The graph titled "Cumulative energy" includes a red line to show the solar contribution to the hot water heating energy. A straight sloping line here indicates consistent day to day performance by the solar water heater. A noticeable curve or angle indicates a change in the operation of the solar water heating system.

Solar Contribution – This is the portion, expressed as percent, of the water heating energy load contributed by solar energy. In essence this is the bottom line of the monitoring.

HX Performance – This is a measure of the average monthly performance of the heat exchanger component of the solar water heating system. It is expressed in BTU/deghr to provide a relative measure of the flow of thermal energy through the heat exchanger in response to a temperature difference between the fluid in the solar loop and the temperature at the bottom of the tank. Ideally, a heat exchanger can be quite complex to monitor because its performance will depend on many factors which are very difficult to monitor, such as natural convection or thermal stratification in the storage tank. Rigorous monitoring of heat exchanger performance is well beyond the scope of this project, due to the needs for complex monitoring and modeling. But some form of comparative heat exchanger monitoring is necessary to validate the proper operation of the system from month to month, and to provide a basis for comparing the operation of systems with different types of heat exchangers. This HX performance parameter is readily established by simple monitoring and it will serve the needs for a comparative heat exchanger performance measurement. The red line on the graph titled "HX Performance" shows the cumulative heat exchange throughput in response to the cumulative temperature difference between the solar fluid and the tank bottom. A noticeable curve or angle in the red line indicates a change in the operation of the heat exchanger during the monthly monitoring period.

DHW Tank Factor – The DHW tank factor measures the losses from the DHW tank to the surrounding space and the connected piping. This factor is defined as the total energy withdrawn from the tank divided by the total energy input to the tank, including all energy input to the tank by the electric element. A good modern tank under typical conditions would have a factor of .93. Typical tanks have factors from .8 to .9.

Solar Tank Factor - The Solar Tank factor measures the losses from the solar tank to the surrounding space and through the connected piping. This factor is defined as the total energy withdrawn from the solar tank divided by the energy input to the solar tank. This factor will vary seasonally with the temperature of the solar tank. The principal use of this factor is to detect thermal losses at night from the solar tank to the solar collectors. Values of this factor below .8 are indicators of potential thermal loss modes.

Daily Energy Flows – The graphs titled "DAILY ENERGY FLOWS" show the the total energy drawn from the DHW system as a blue line and the total solar energy input to the system as a red line. These energy flows are expressed as BTU/hour.

Review of the summary and graphic output reveals the following:

1. At Philadelphia, DHW2 - Monitoring for May under actual Philadelphia usage and site conditions shows the solar water heater producing a 61% contribution for May. This is consistent with the design expectation for this system. The solar contribution can reasonably be expected to increase as the summer proceeds.

2. At Philadelphia, DHW2 - The hot water usage at this installation in May was 98 gallons/day. The solar contribution of 23,086 BTU/day is reasonable for a system of this type. The solar tank factor of 1.44 is not reasonable because it implies more energy removed from the solar tank than was input. This suggests an error in one or more of the solar loop temperatures. The solar loop temperatures at all sites should be checked and re-calibrated. Inspection of the monitoring data shows an unusually low temperature difference through the collectors.

3. At Philadelphia, DHW3 - The solar return(down) temperature is unusually high for about an hour on sunny mornings. Some high temperatures can be expected when the pump first starts, but not nearly so much as was observed. A sunny morning flow irregularity is indicated. The situation is illustrated in the graph in the performance note comparing operation at sites 2 and 3 on May 9 and 10. On these sunny days, it appears that the pump at site 3 starts almost an hour later than at site 2. The temperature of the fluid from the collectors is also much higher for site 3 than for site 2. The PV panel at site #3 is only 10 watts compared to a 20 watt panel at site #2. The smaller PV panel at site #3 could explain the later pump start. Action items here are: a) to evaluate the use of a 10 watt panel in this type of installation and b) to examine the piping of this system for kinks or air traps.

4. At Philadelphia, DHW2 - The heat exchanger shows a deteriorating performance factor for May compared to prior months. Since this factor is calculated from solar loop measurements, it will need to be corrected when the solar loop temperatures at this site are re-calibrated.

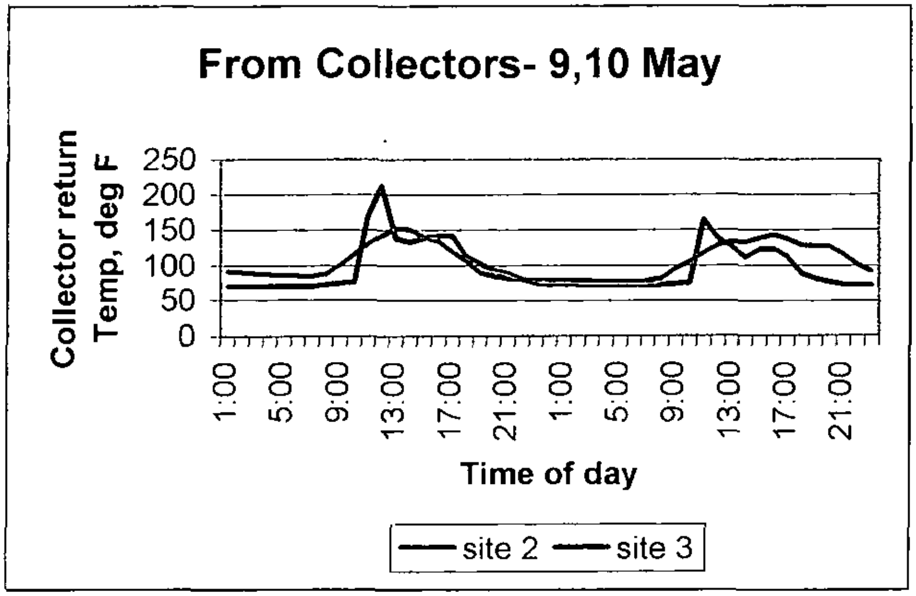
5. At Eugene, DHW1 – Monitoring at this site is limited to the solar storage tank and the heat exchanger. This site shows a DHW use of 85 gallons/day, which is reasonable for this size family. Solar collection has increased significantly during March and April. The heat exchanger performance appears to be consistent as the solar collection increases. The solar tank factor however is decreasing with the increased solar collection, indicating a possible night thermal loss mode. Further monitoring during sunnier weather and careful calibration of the PV pump will confirm the long term performance expectation for this configuration relative to the Philadelphia sites.

6. At all three sites – Heat exchanger performance is a significant monitoring objective at all sites because heat exchanger performance significantly affects overall system performance. The PV pump flow calibrations and the solar loop temperature calibrations will refine the heat exchanger performance estimates. A simple energy flow model has been constructed for each site which can utilize the heat exchanger

performance measurements to predict annual system performance for systems employing different types of heat exchangers and collectors.

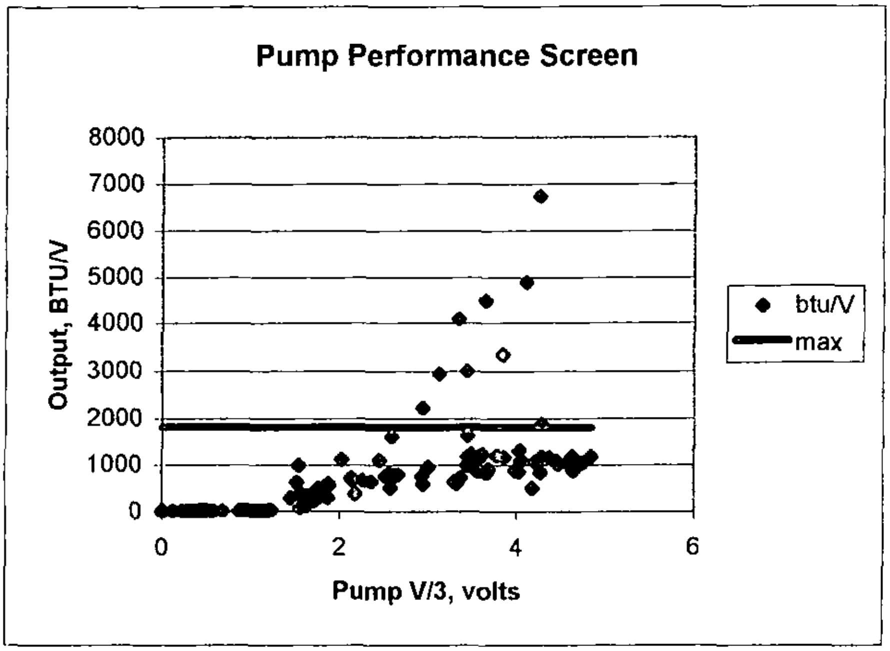
PERFORMANCE NOTE - Site 3 - May 23, 2000

Site 3 shows unusually high temperatures for early morning operation. Both sites 2 and 3 are located in Philadelphia, 2 in NE, 3 in SW, and the data below is taken for the same days: May 9 and May 10.



The temperature of the fluid returning from the collectors is initially very high, then it reaches a reasonable value for afternoon performance.

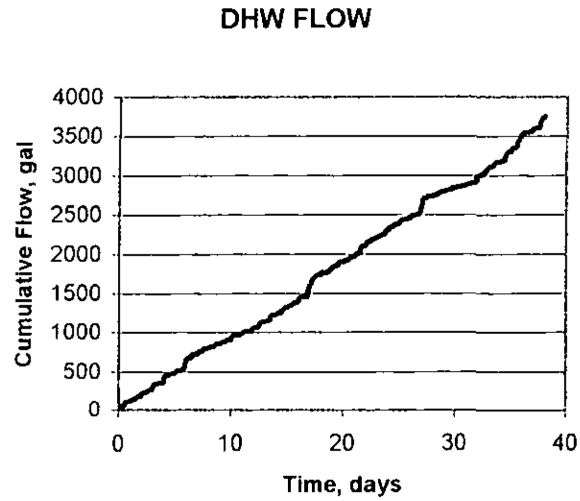
Data for the first two weeks operation at site 3 shows these same initial high temperatures on most fully sunny mornings. These high temperatures indicate a high thermal loss situation or possibly a restricted flow situation. A pump performance test has been devised to screen for such operation.

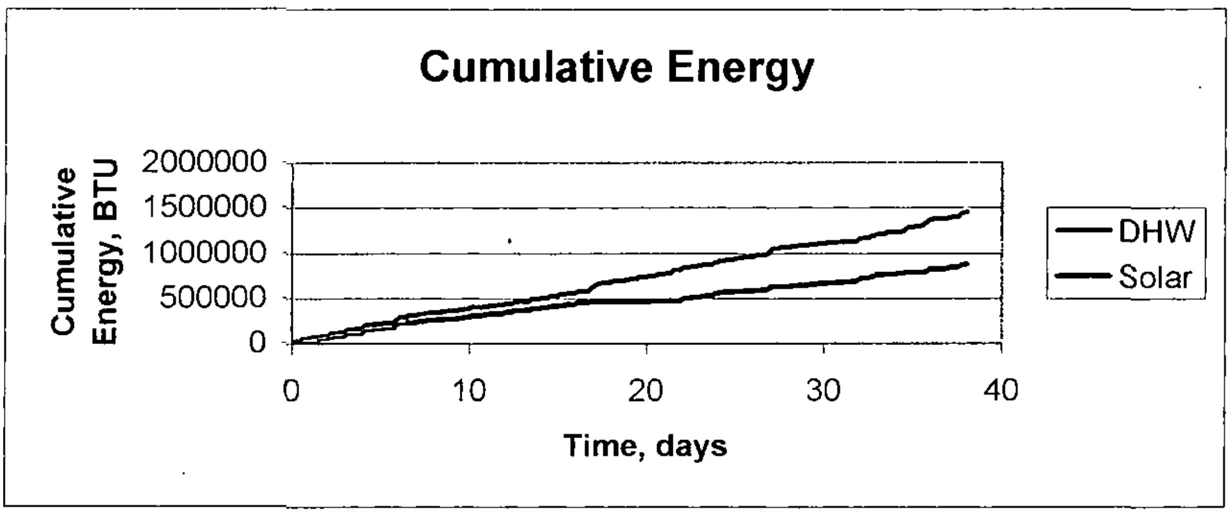


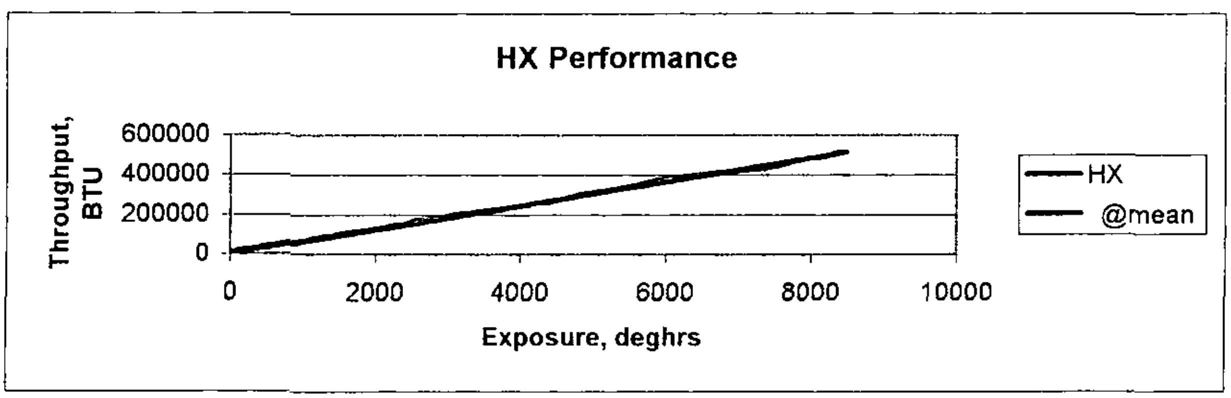
At site 3 this screen shows 8 hours of operation at high levels of thermal output clearly above the theoretical maximum for this system. These "impossible" values suggest two possibilities: 1) the flow is not as high as expected by site flow vs Volts measurements because of cavitation or partial blockage, or 2) the electronically commutated pump may have different pump performance curves under certain conditions.

SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont7.xls

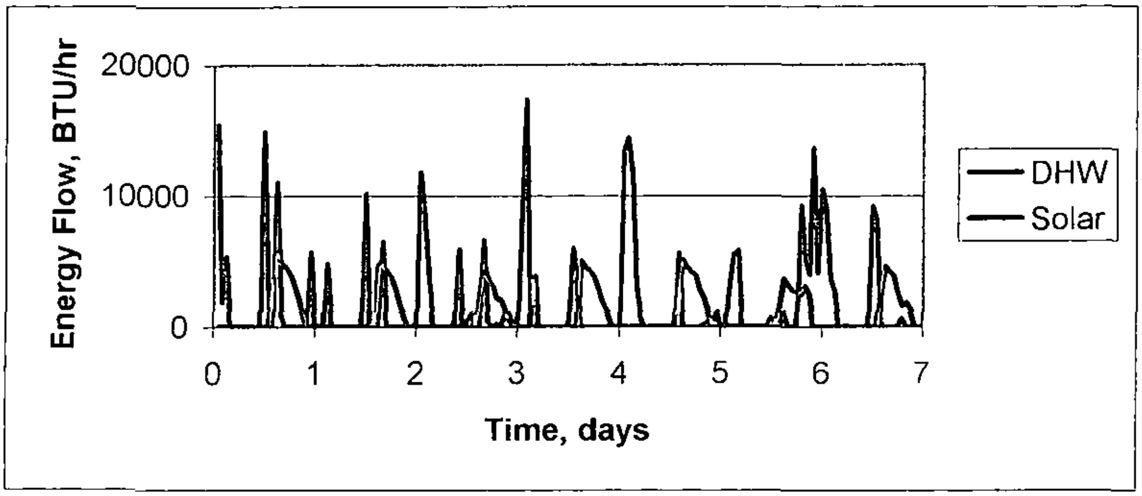
Start date	end date	
03-May-00	10-Jun-00	
Month	may	
Duration	38.04	days
Mean Inlet Temp	68.2	deg F
Mean Outlet Temp	114.4	deg F
Mean DHW usage	98.9	gal/day
Mean DHW BTU/day	38,121	BTU/day
Mean Solar BTU/day	23,086	BTU/day
Solar Contribution	61%	
HX Performance	61	BTU/deghr
DHW tank factor	0.85	
Solar tank factor	1.44	

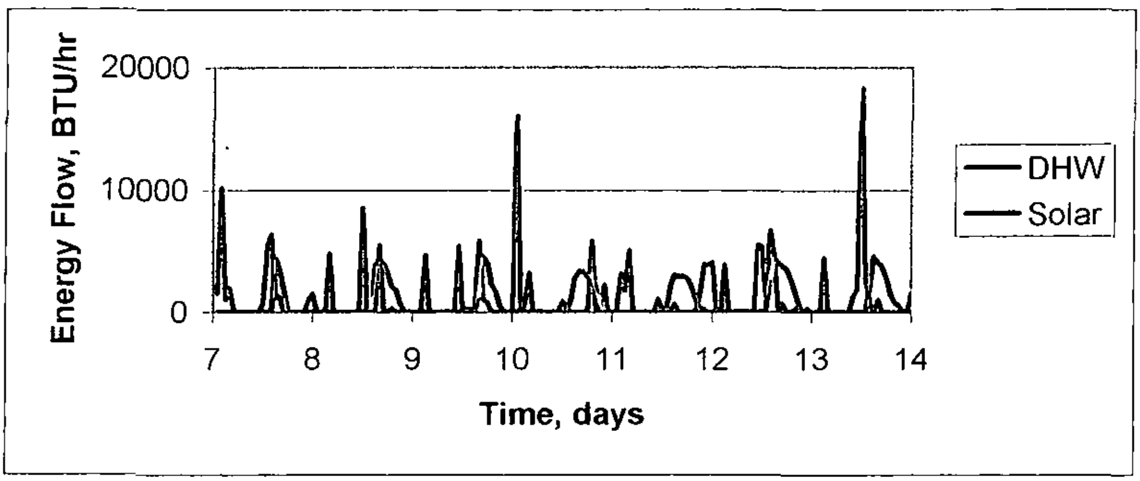


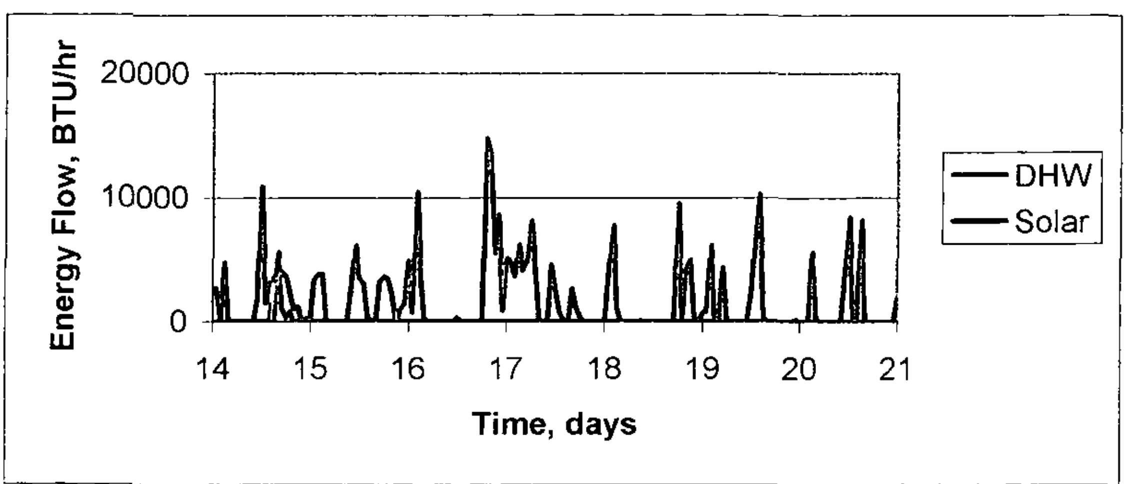


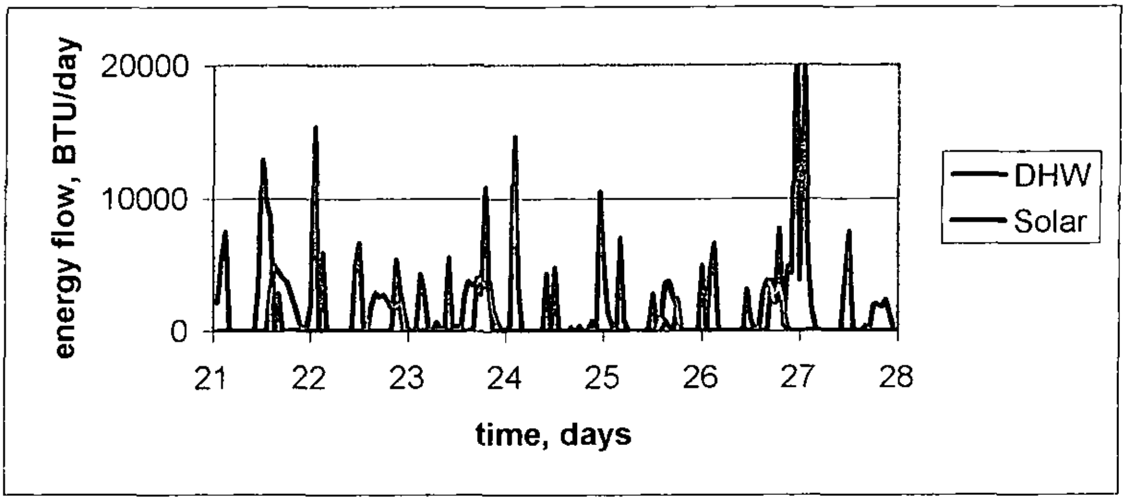


DAILY ENERGY FLOWS

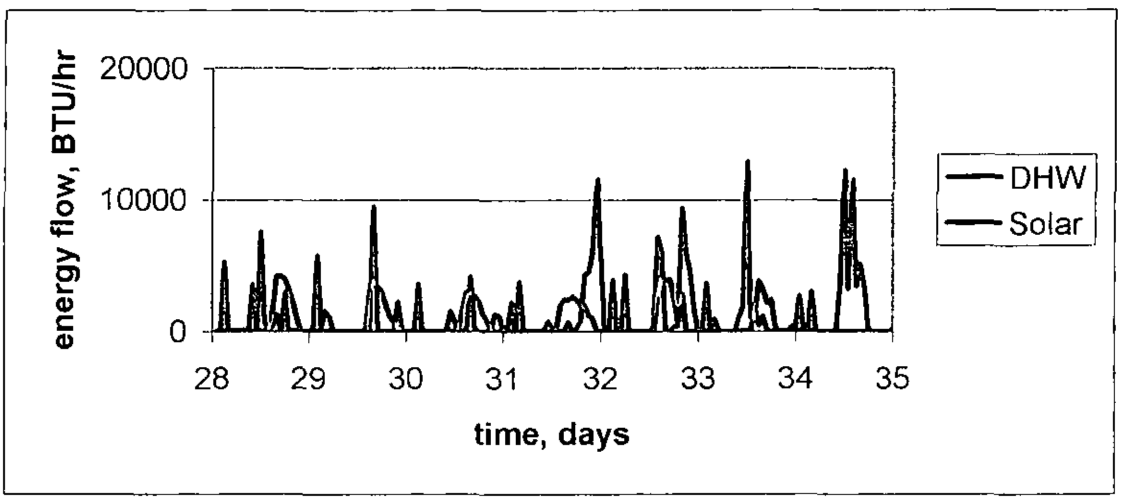




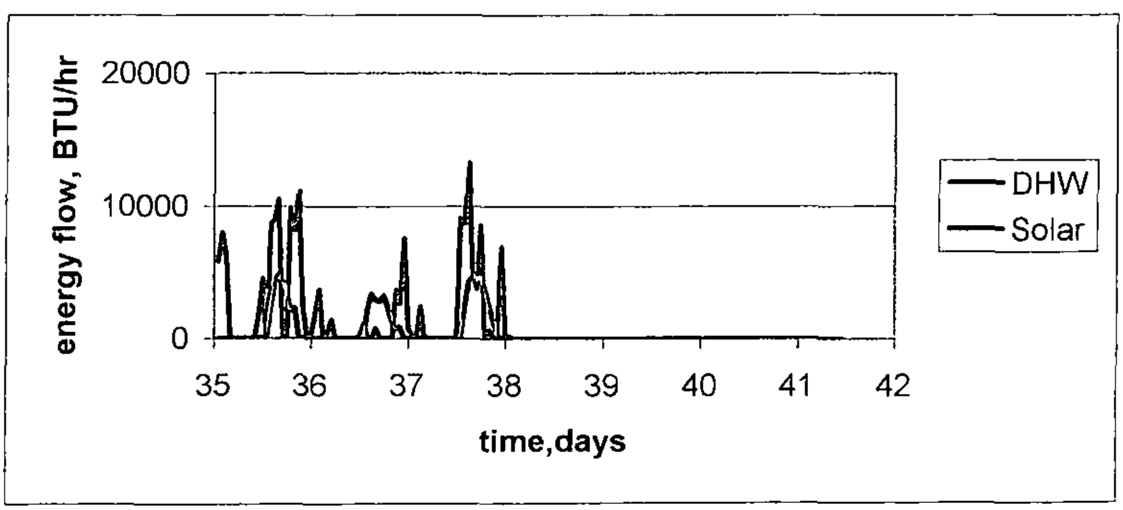




energy flow, BTU/day
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar



energy flow, BTU/hr
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar



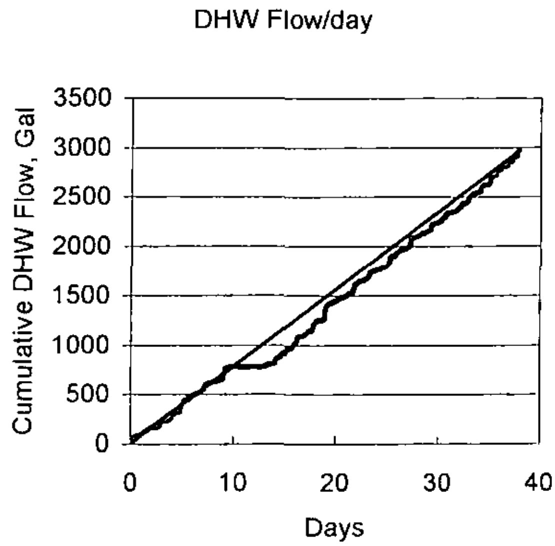
energy flow, BTU/hr
20000
10000
0
35
36
37
38
39
40
41
42
time,days
DHW
Solar

SOLAR DHW SYSTEM MONITORING SUMMARY

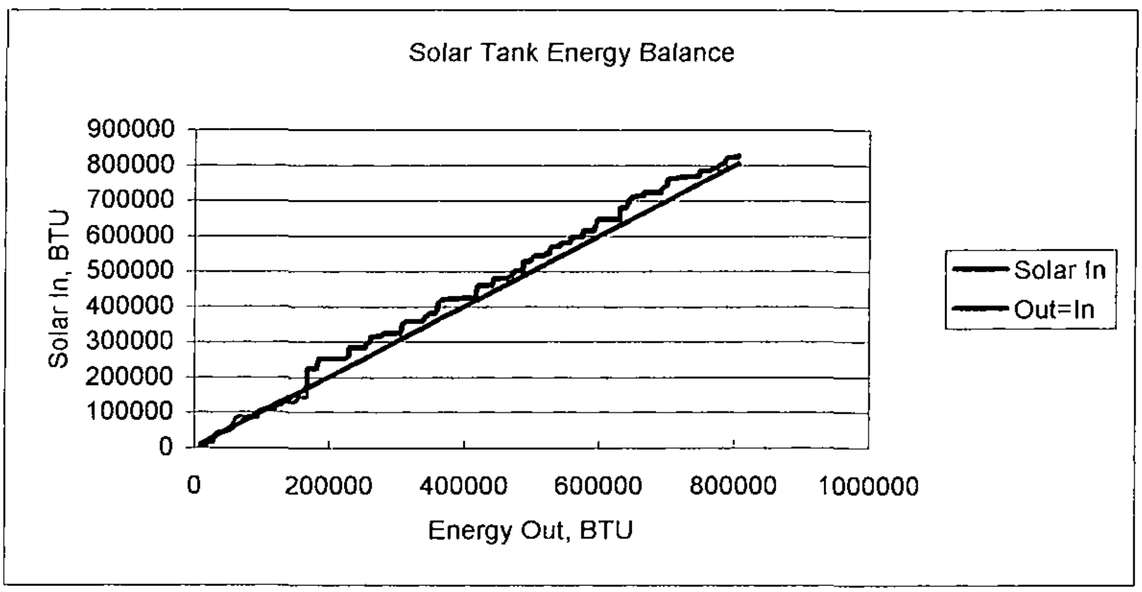
System: DHW1- lemer8f.xls

Monitoring Period: 2 May 2000 to 9 June 2000

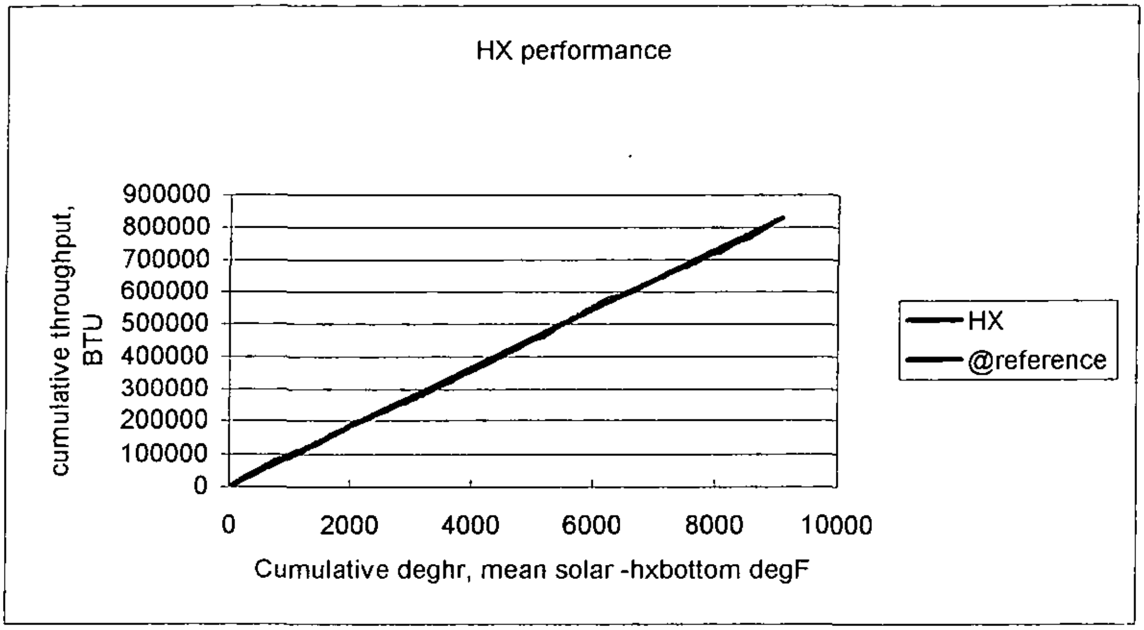
Month	apr
Duration	37.9 days
Mean Inlet Temp	59.4 deg F
Mean Outlet Temp	92.0 deg F
Mean DHW usage	78.3 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	21234 BTU/day
Solar Contribution	not monitored
HX Performance	91.344697 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.97



DHW flow is approximately constant at 80 gallons/day.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be storing its energy during the night; no serious night losses are evident.

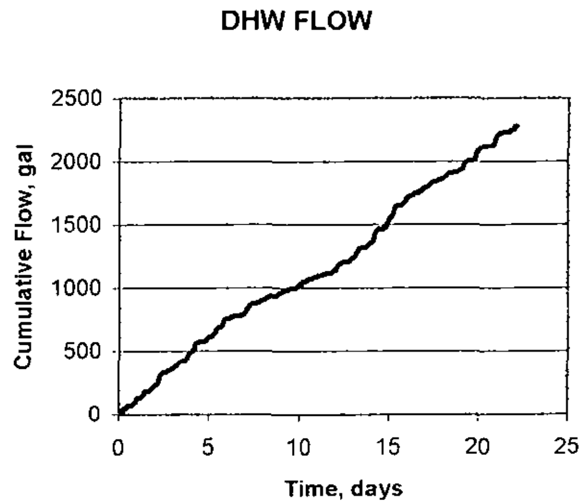


The HX performance is consistent with the improved performance of the replacement heat exchanger.

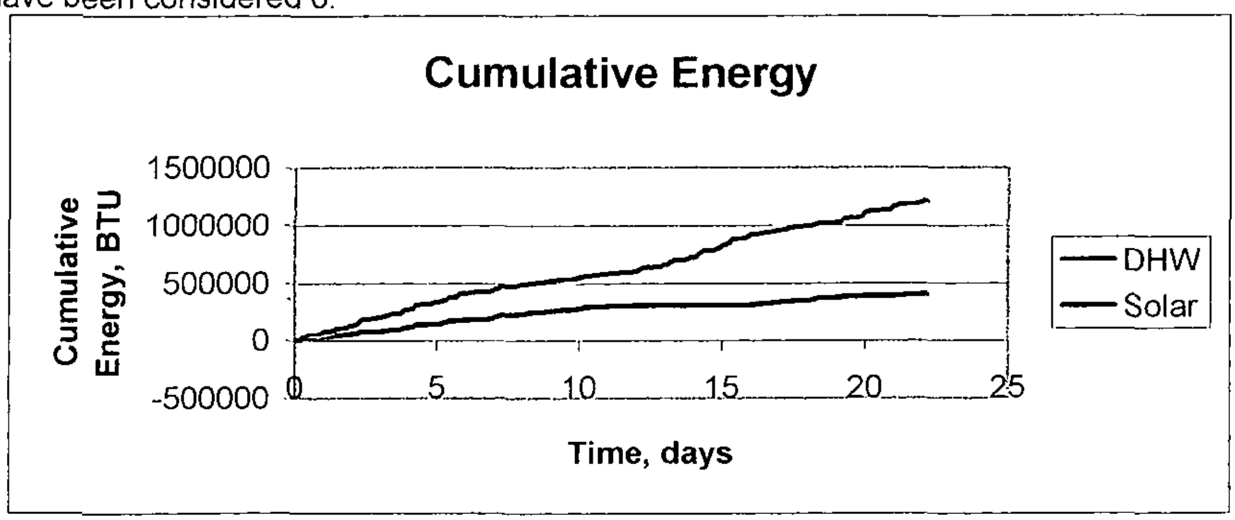
SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strelau3.xls

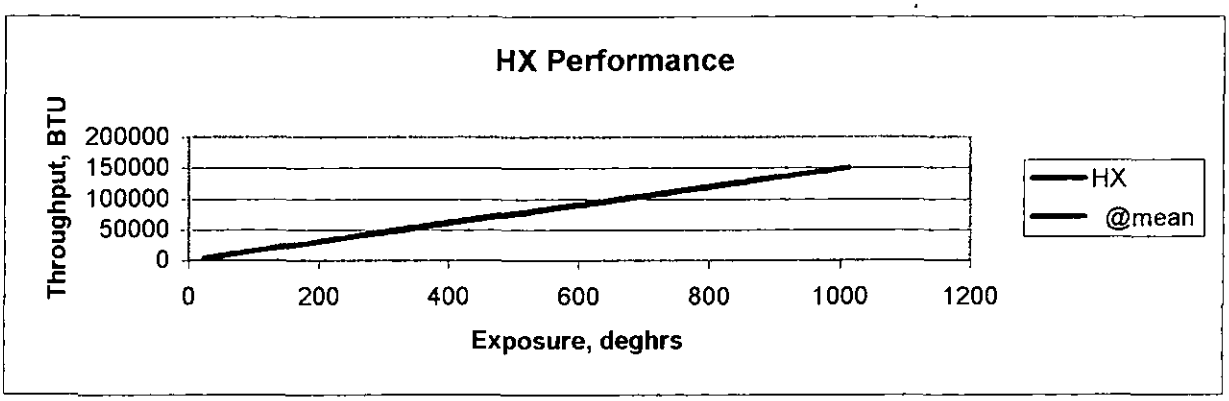
Start date	start hr	end date	end hr
08-May-00	14:00	30-May-00	17:00

Month	may	
Duration	22.17	days
Mean Inlet Temp	69.4	deg F
Mean Outlet Temp	133.3	deg F
Mean DHW usage	102.8	gal/day
Mean DHW BTU/day	54,704	BTU/day
Mean Solar BTU/day	18,295	BTU/day
Solar Contribution	33%	
HX Performance	148	BTU/deghr
DHW tank factor	1.08	
Solar tank factor	1.43	

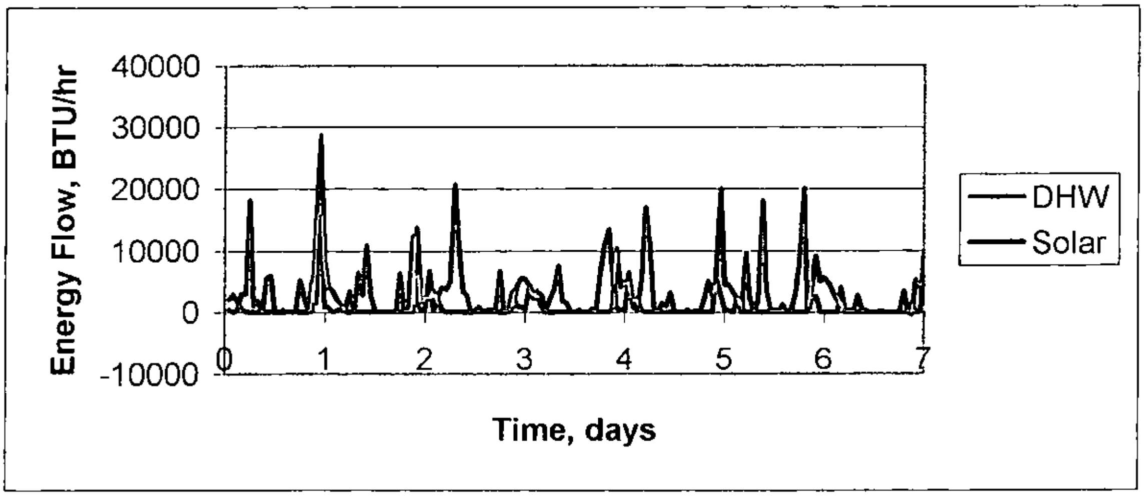


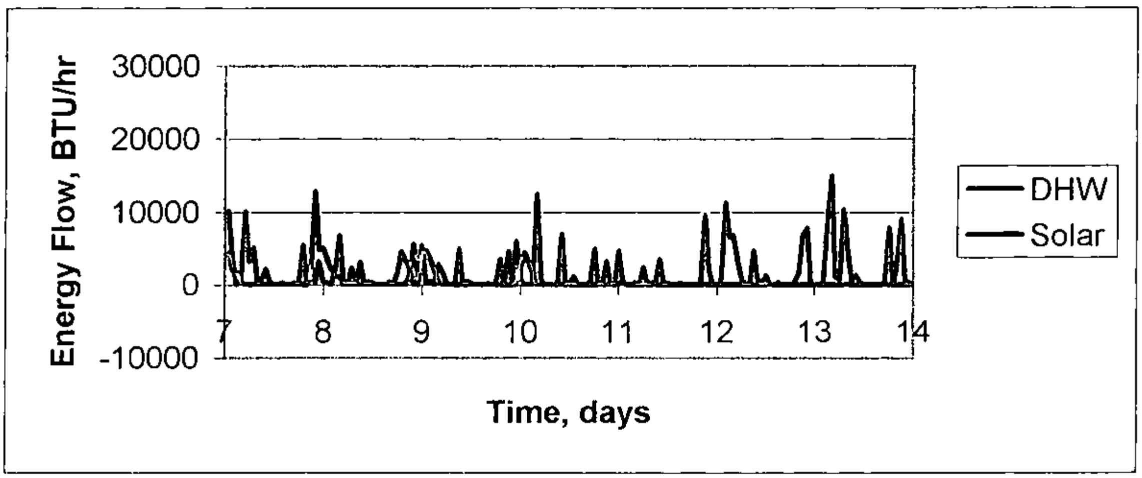
solar yields with unreasonable high temps have been considered 0.

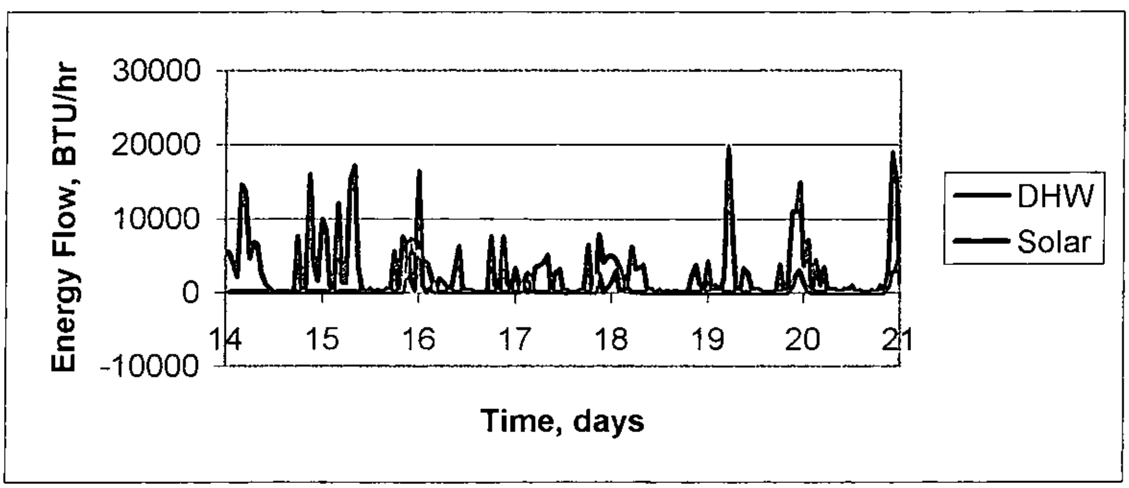


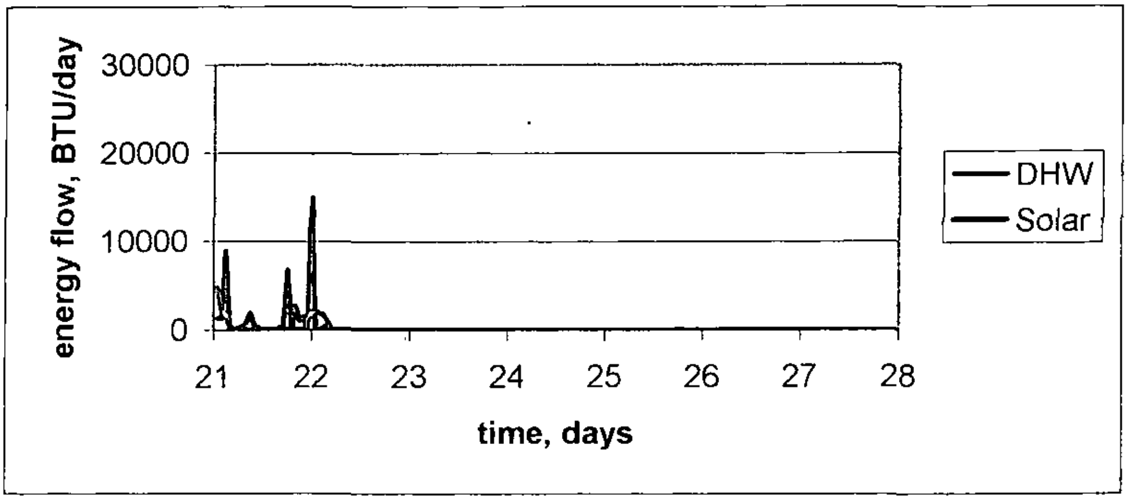


DAILY ENERGY FLOWS

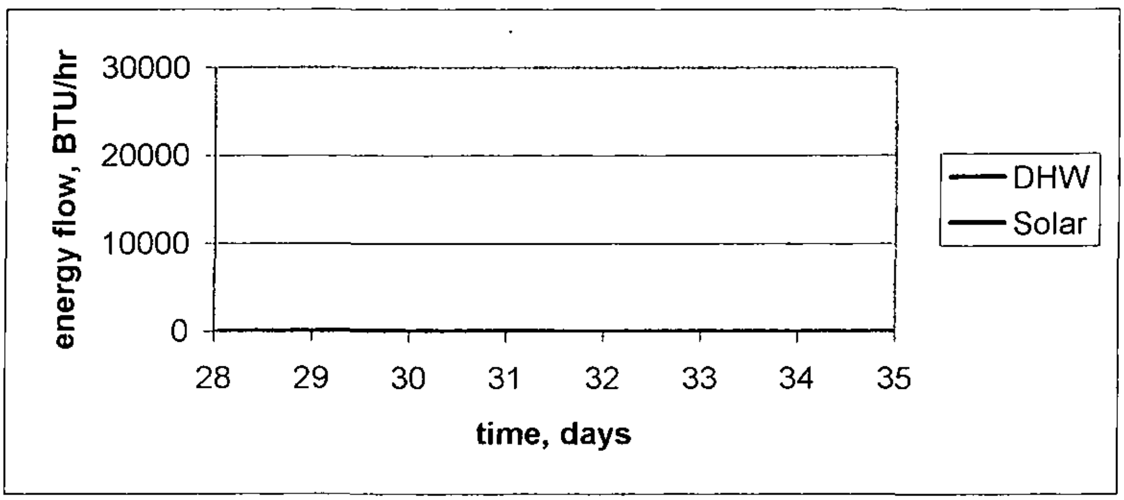




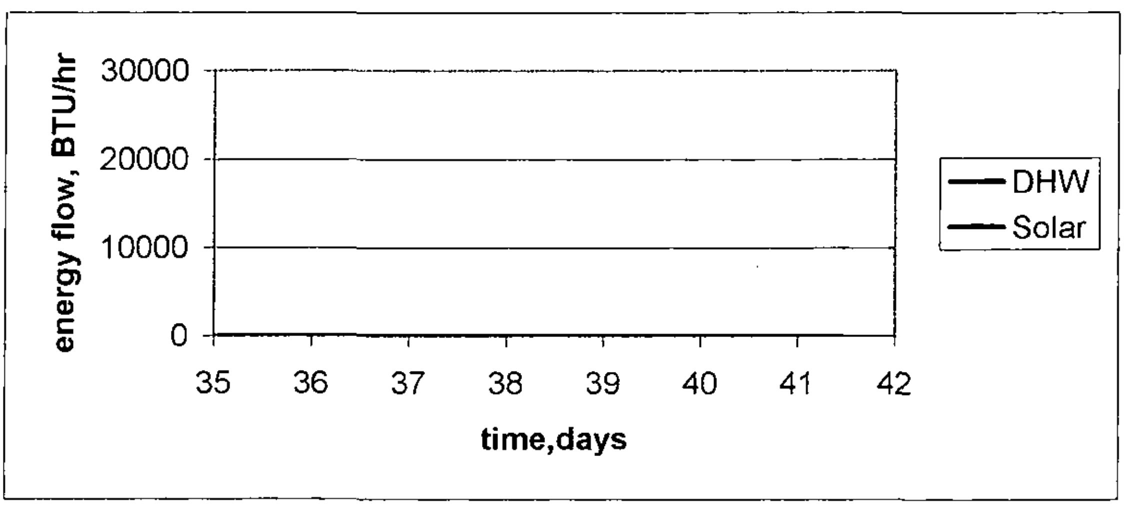




energy flow, BTU/day
30000
20000
10000
0
21
22
23
24
25
26
27
28
time, days
DHW
Solar

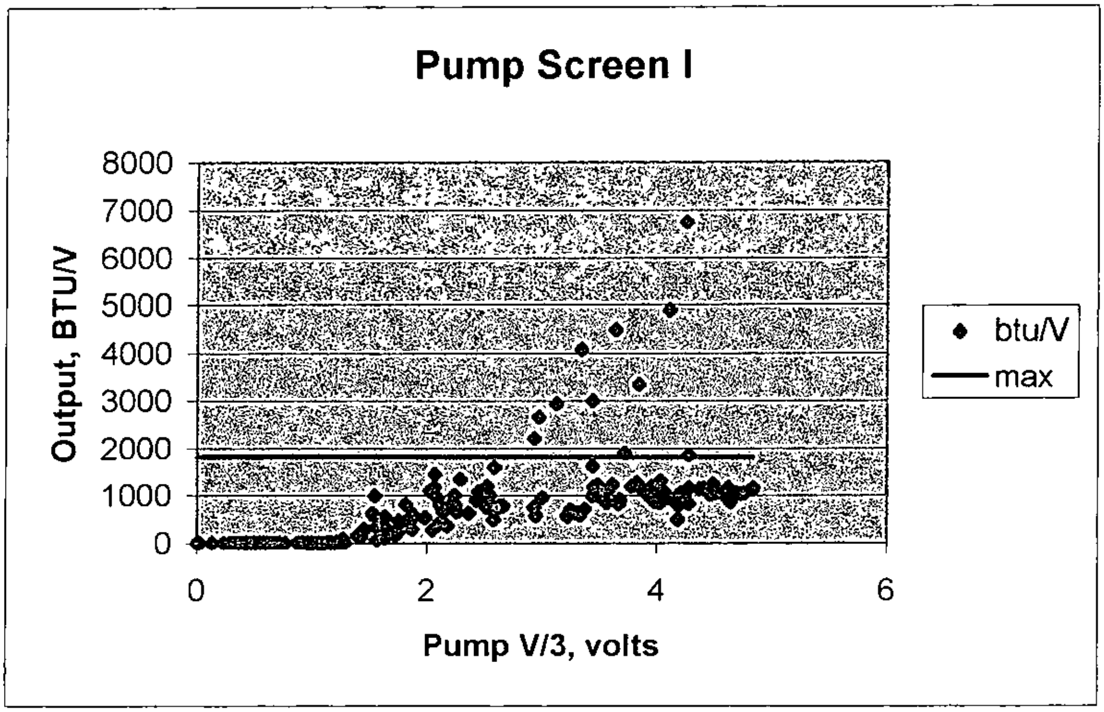


energy flow, BTU/hr
30000
20000
10000
0
28
29
30
31
32
33
34
35
time, days
DHW
Solar



energy flow, BTU/hr
30000
20000
10000
0
35
36
37
38
39
40
41
42
time,days
DHW
Solar

PUMP PERFORMANCE



The pump performance is anomalous for at least ten hours of the monitoring period. This unusual performance is evident by very high fluid temperatures in the fluid returning from the collectors. At these high temperatures the collected energy is much more than the incident energy. There are three possible explanations:

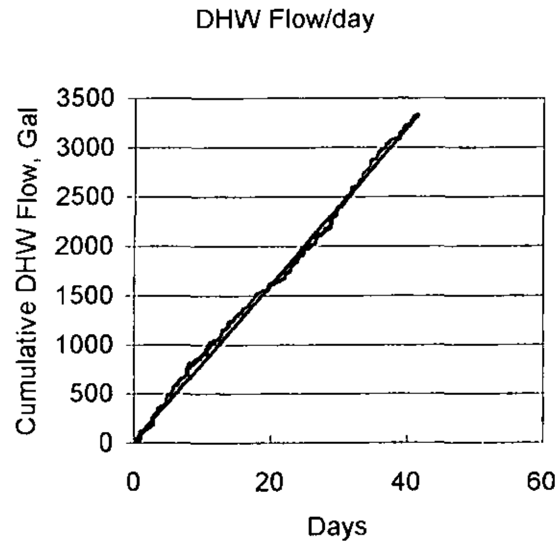
1) energy is stored in the mass of the collector
2) at these times the flow is not as predicted by the flow vs V curve
3) the pump has more than one operating curve.

In this graph, points above the pink line have a calculated thermal output that is probably impossible under the observed conditions.

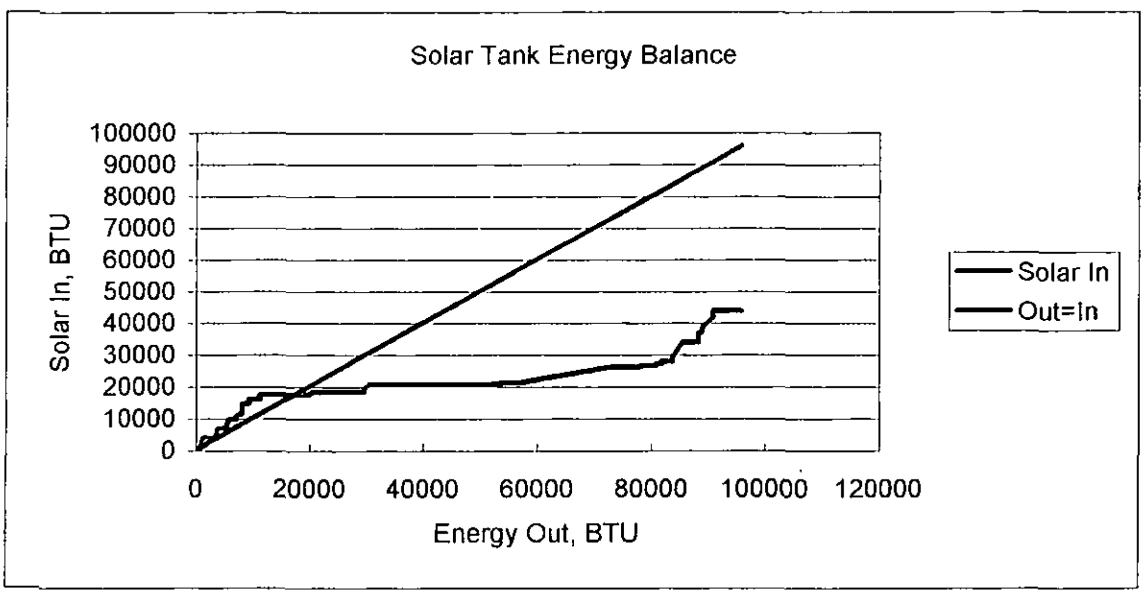
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer4f1.xls

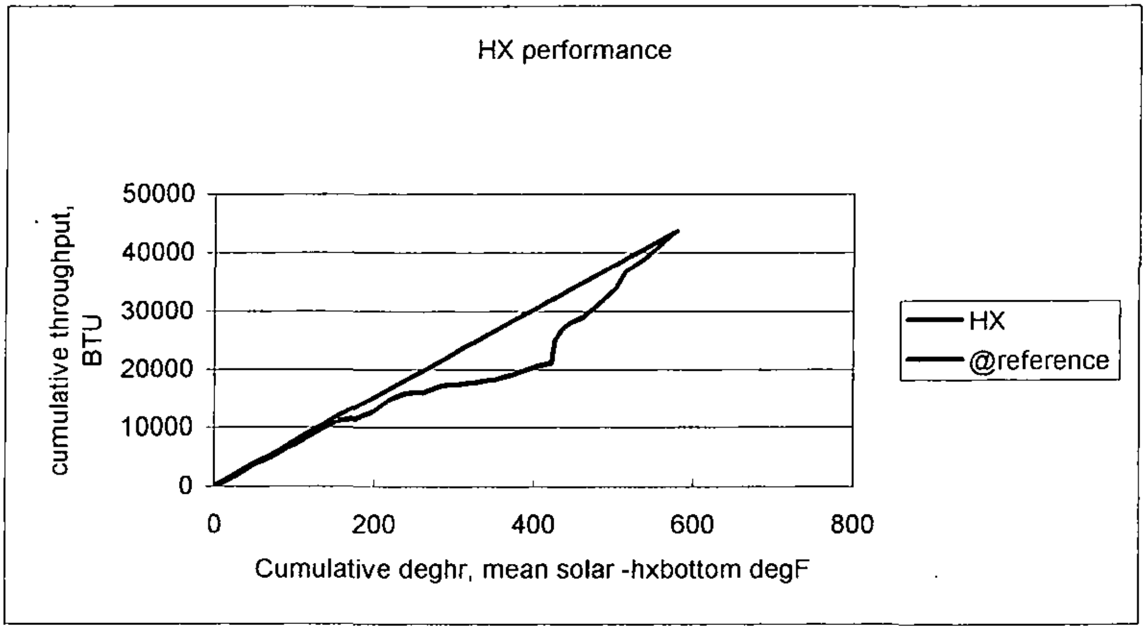
Begin	end
20-Dec-99	30-Jan-00
Month	Jan
Duration	41.5 days
Mean Inlet Temp	57.2 deg F
Mean Outlet Temp	60.6 deg F
Mean DHW usage	80.0 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	2,311 BTU/day
Solar Contribution	not monitored
HX Performance	75.42 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	2.19
Incident Solar	148 BTU/ft2/day
Mean Efficiency	26%



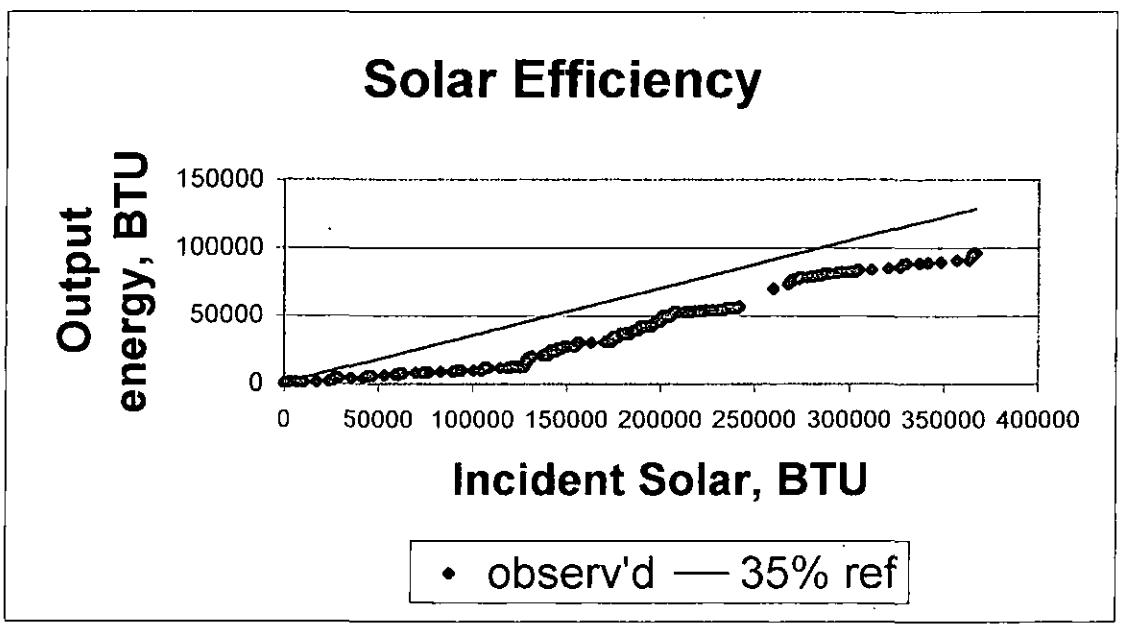
DHW flow is approximately constant at 80 gallons/day.



Solar input is not significant for most of the monitoring period. Tank is gaining energy from its warmer interior surroundings, leading to a tank factor greater than 1.



The heat exchanger was changed during this monitoring period. The new heat exchanger appears to have better performance than the old one, but the new exchanger has much more flow resistance than the old one. The flow equation for the old exchanger is gpm=.35*V-.09, and for the new exchanger, gpm=.14*V-.06. The new heat exchanger is an improvement, but not a huge improvement. Poor performance in midspan is probably due to sluggish pumping.A18

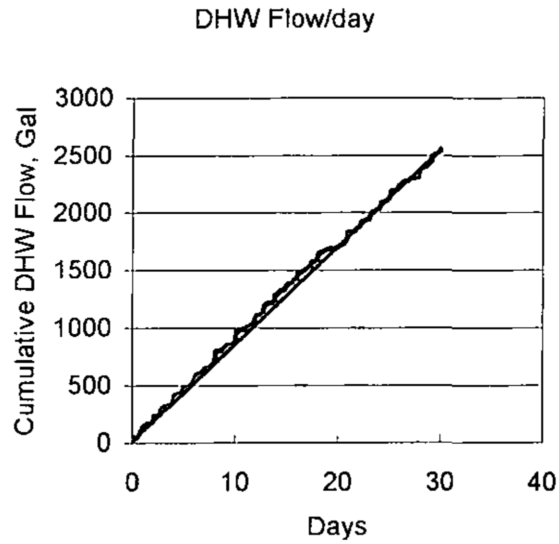


Solar efficirncy appears to increase with the improved heat exchanger, but there is so little solar in this period that this measurement is weak, Initial solar output appears to be tank gain from surro

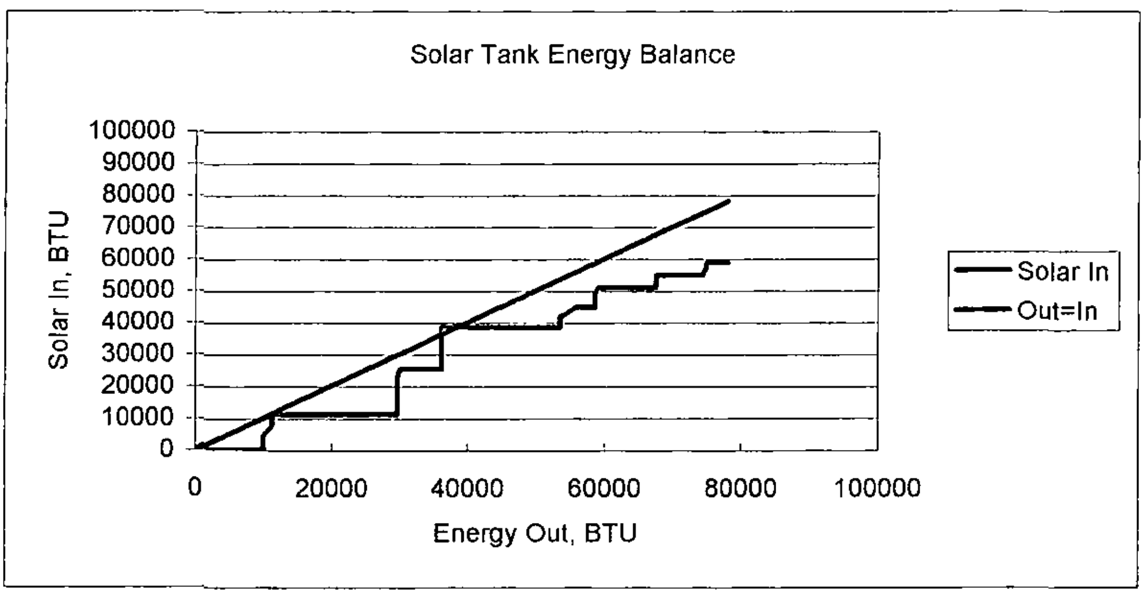
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer5f1.xls

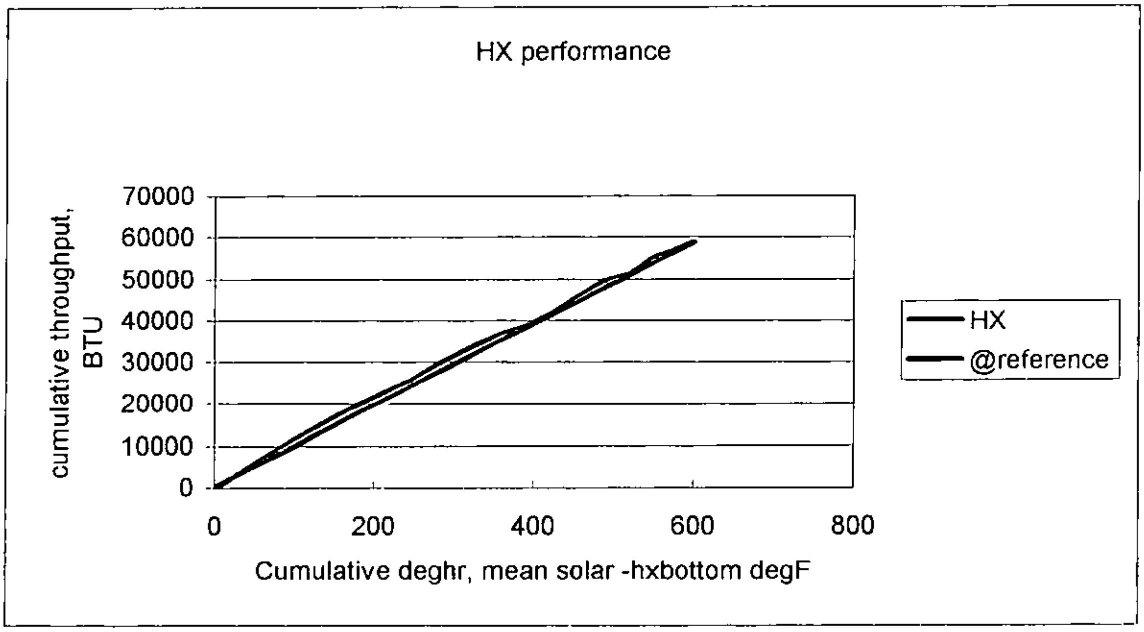
Begin	end
30-Jan-00	29-Feb-00
Month	Feb
Duration	30.1 days
Mean Inlet Temp	57.2 deg F
Mean Outlet Temp	60.8 deg F
Mean DHW usage	84.9 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	2,599 BTU/day
Solar Contribution	not monitored
HX Performance	97.61 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	1.33
Incident Solar	215 BTU/ft2/day
Mean Efficiency	20%



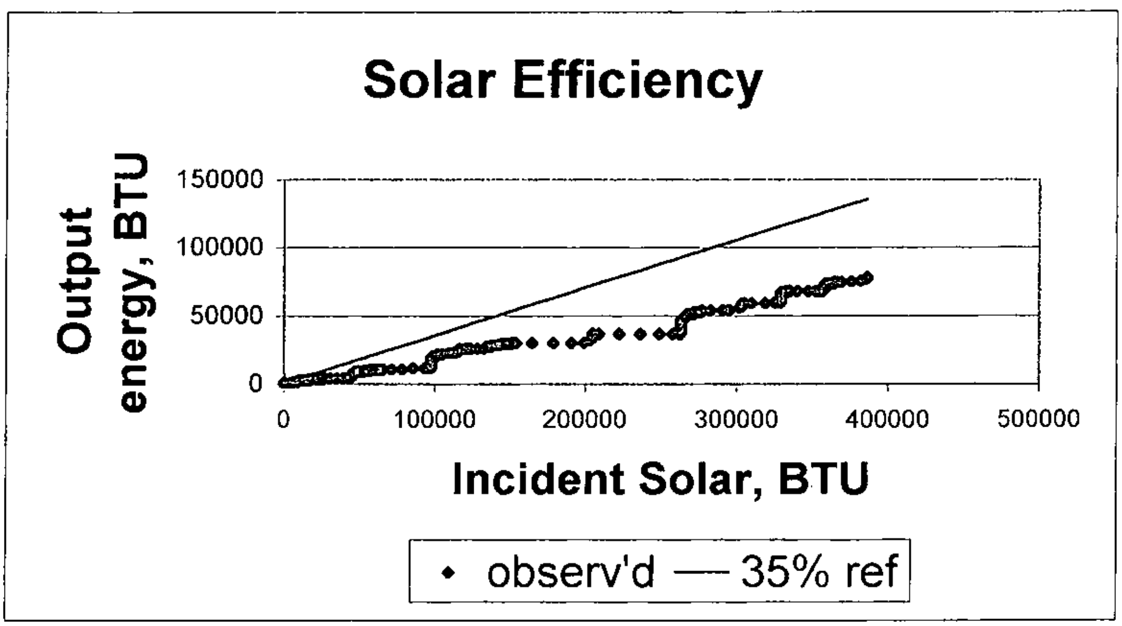
DHW flow is approximately constant at 85 gallons/day.



Solar input is not significant for most of the monitoring period. Tank is gaining energy from its warmer interior surroundings, leading to a tank factor greater than 1.



The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.

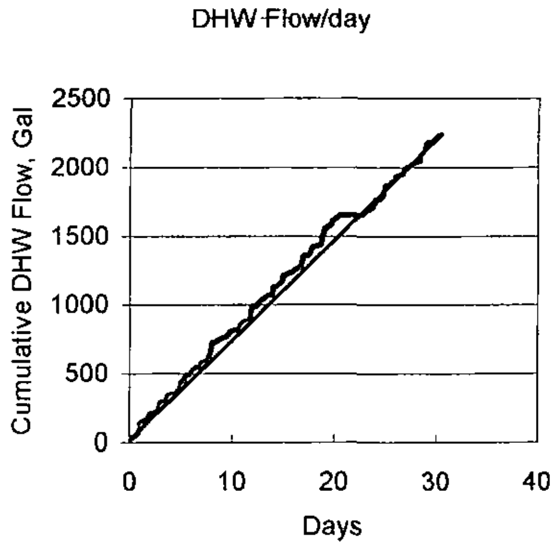


Solar efficiency is low because the pump does not turn on for most of the period. Incident solar is very weak. There are only a few solar collection days in the period.

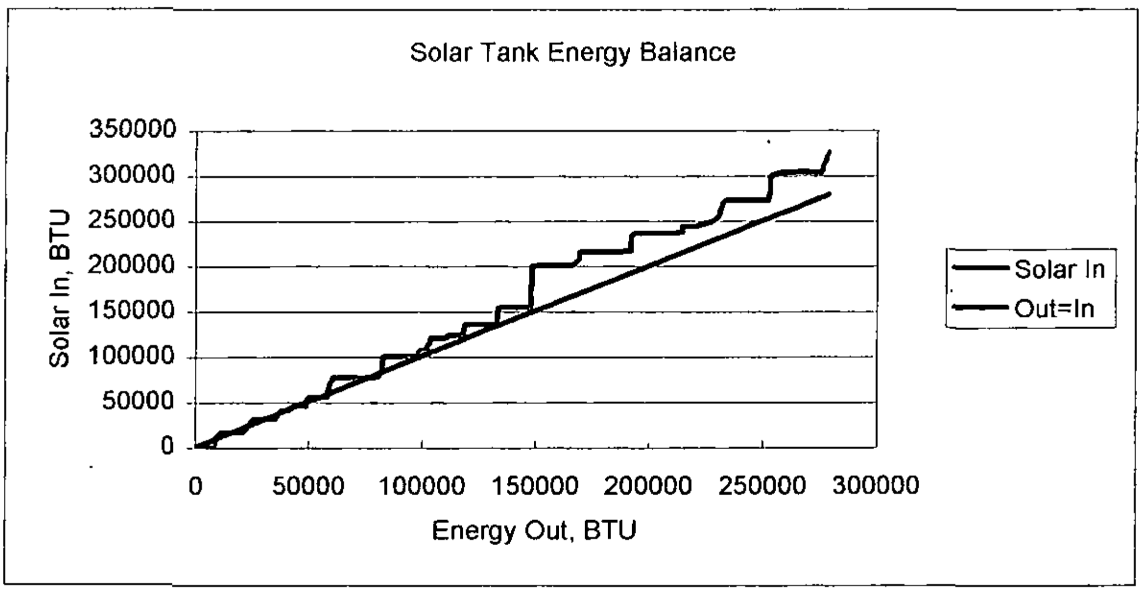
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer6f1.xls

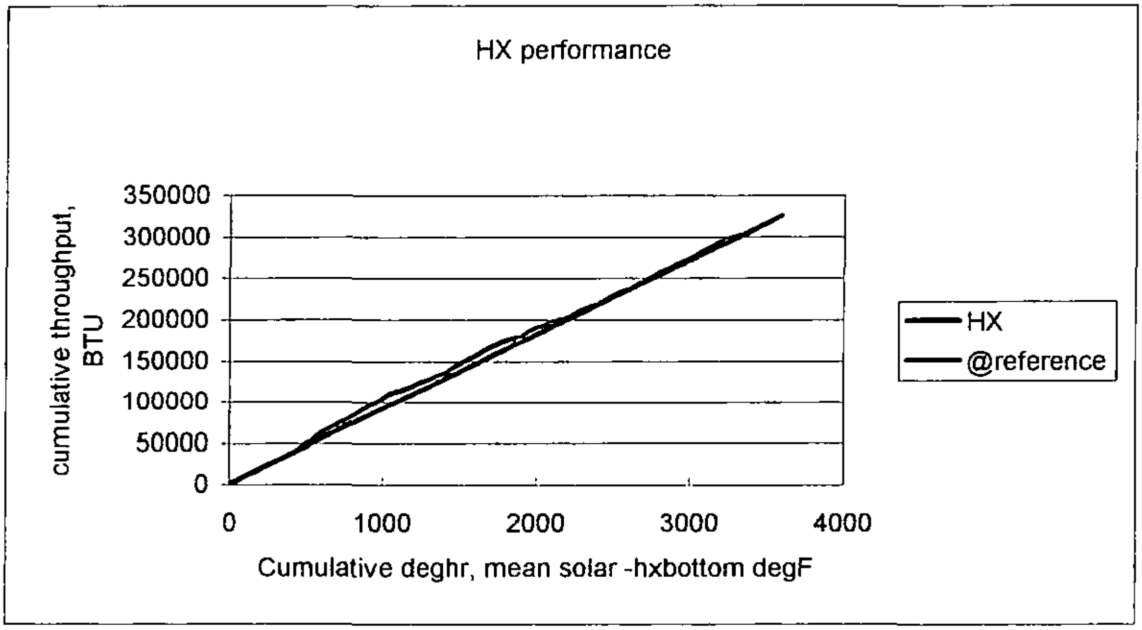
Begin	end	
1-Mar-00	31-Mar-00	
Month	Mar	
Duration	30.5	days
Mean Inlet Temp	57.7	deg F
Mean Outlet Temp	72.7	deg F
Mean DHW usage	73.2	gal/day
Mean DHW BTU/day	not monitored	
Mean Solar BTU/day	9,152	BTU/day
Solar Contribution	not monitored	
HX Performance	90.53	BTU/deghr
DHW tank factor	not monitored	
Solar tank factor	0.86	
Incident Solar	667	BTU/ft2/day
Mean Efficiency	23%	



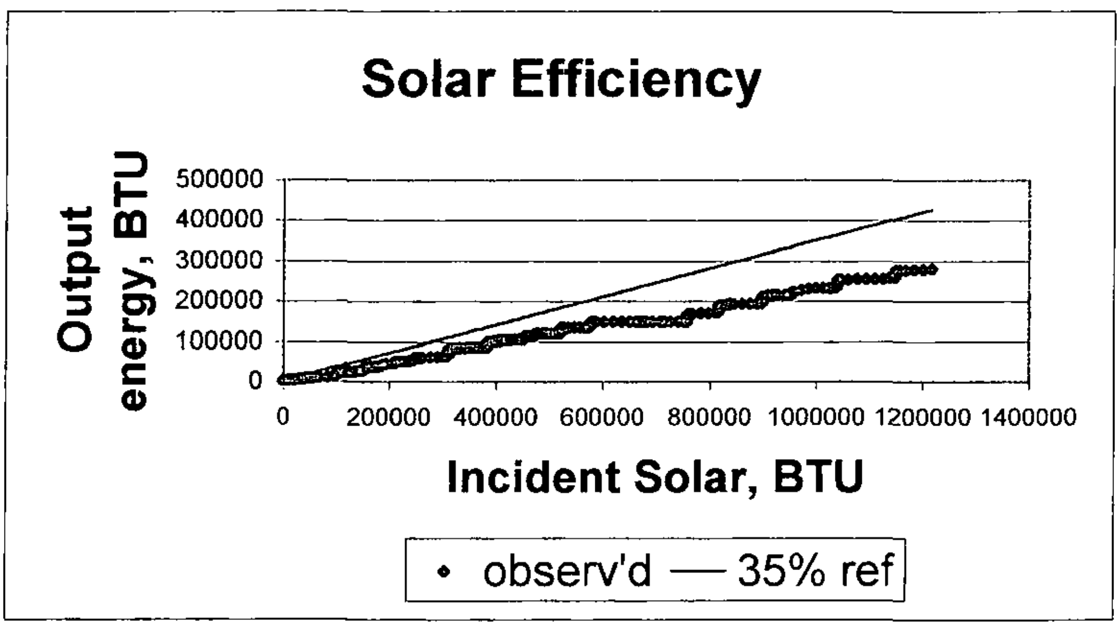
DHW flow is approximately constant at 85 gallons/day, but mean flow is less because of inactivity for several days at days 17-20.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be storing its energy during the night; no serious night losses are evident. Tank loss factor here is somewhat low because of standby losses during several days of non-use.



The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.



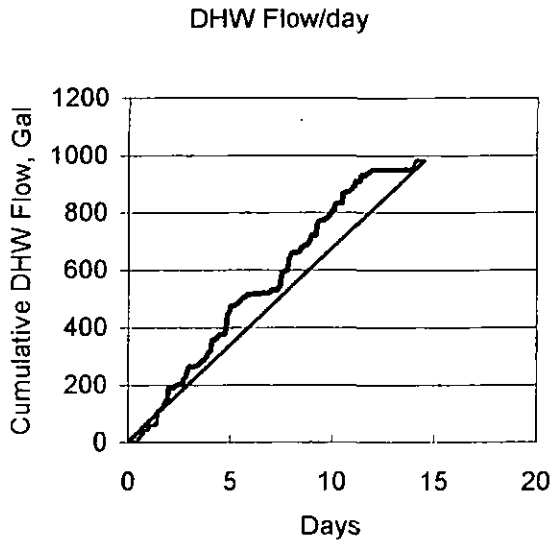
Solar efficiency is reduced by the brief period of non-use.

SOLAR DHW SYSTEM MONITORING SUMMARY

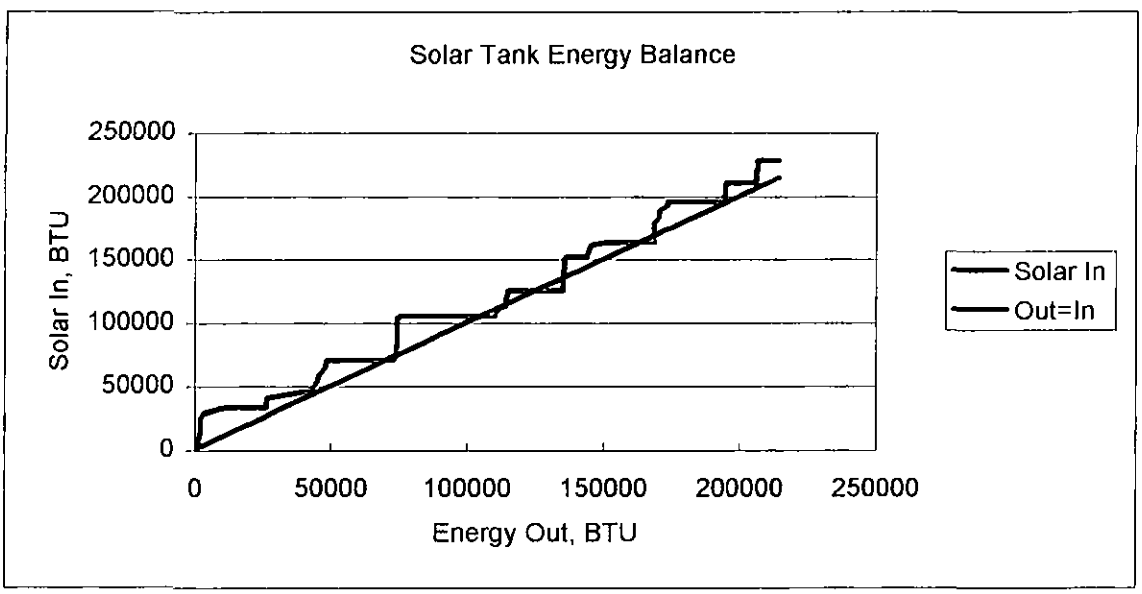
System: DHW1- lemer7f1.xls

Begin	end
1-Apr-00	16-Apr-00
Month	Apr
Duration	14.5 days
Mean Inlet Temp	58.4 deg F
Mean Outlet Temp	84.6 deg F
Mean DHW usage	67.6 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	14,796 BTU/day
Solar Contribution	not monitored
HX Performance	91.26 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.94
Incident Solar	923 BTU/ft2/day
Mean Efficiency	27%

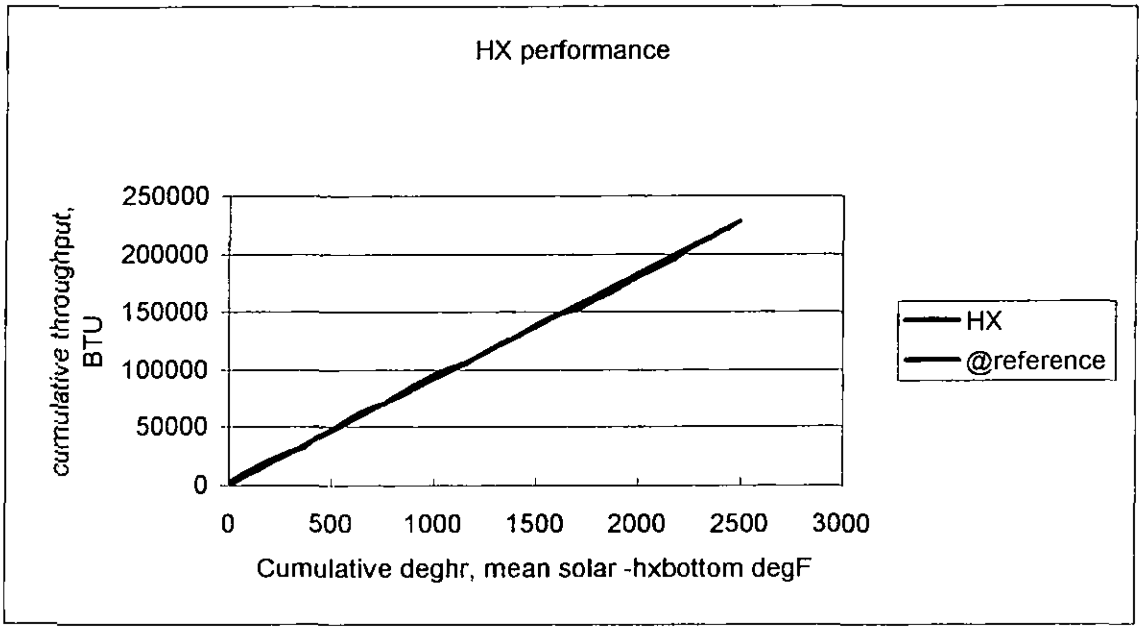
Data was lost for the last half of April due to a communications failure.



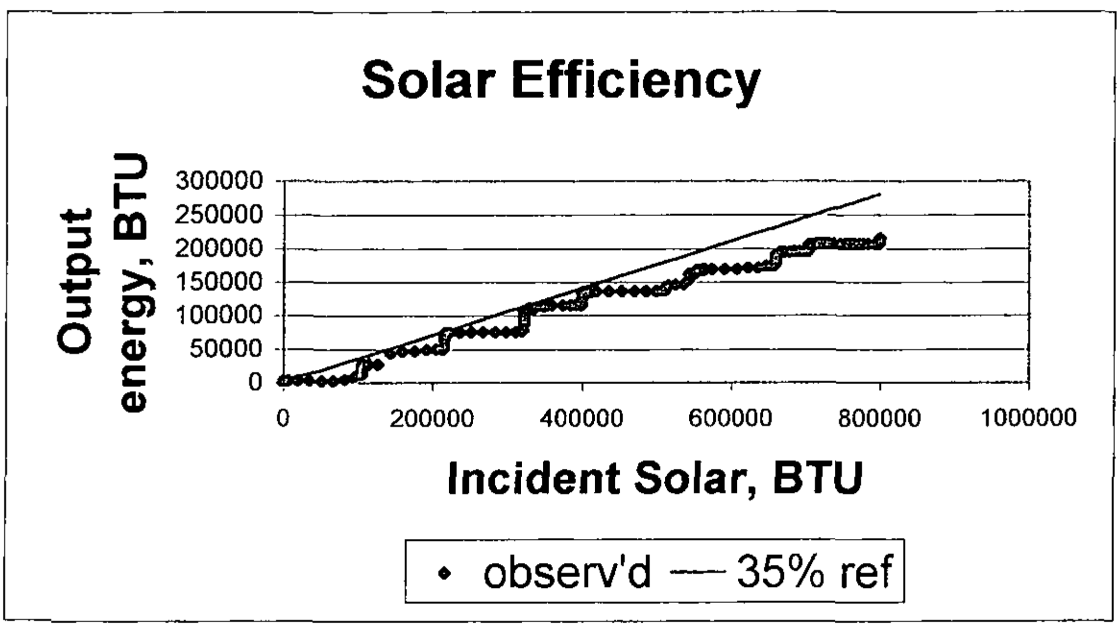
DHW flow is approximately constant at 85 gallons/day, but mean flow is less because of inactivity for several days at days 5-7 and 10-12.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be storing its energy during the night; no serious night losses are evident.



The HX performance is consistent with the improved performance of the replacement heat exchanger.

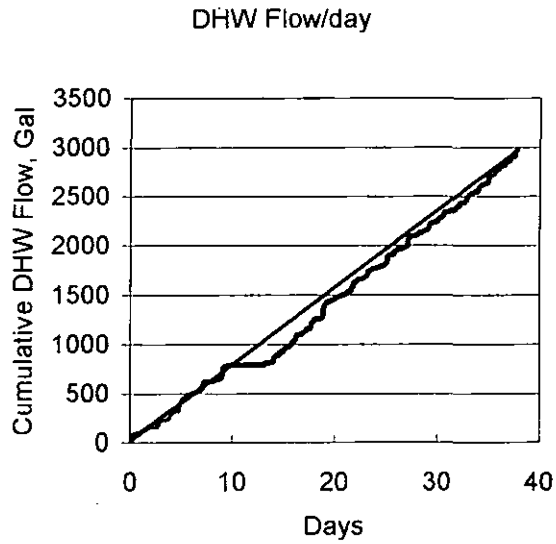


Solar efficiency may be somewhat reduced because of non usage at the end of the test period.

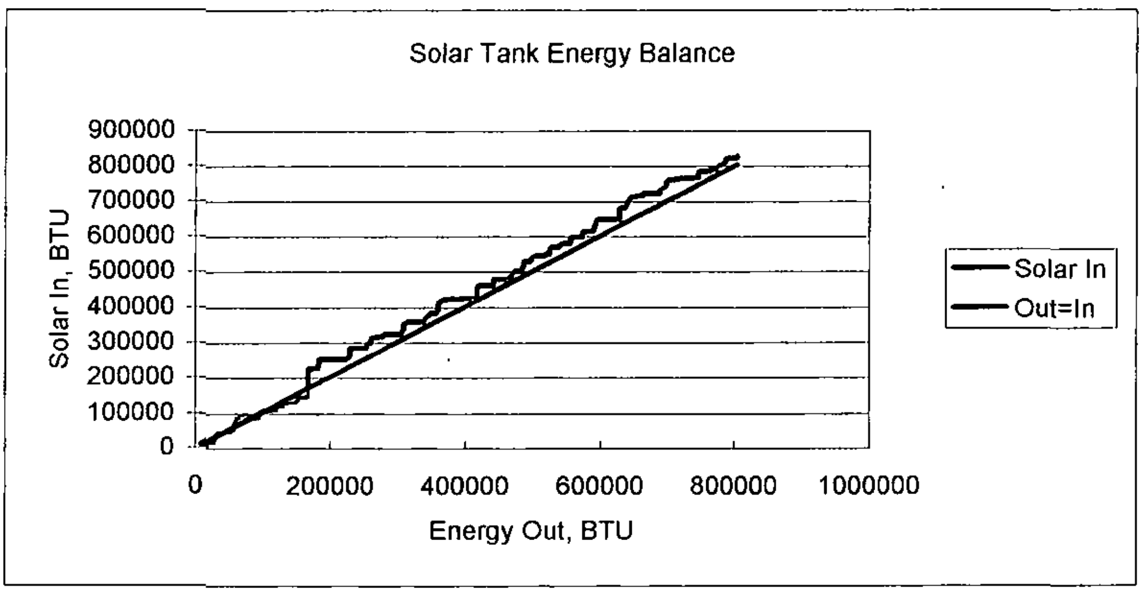
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer8f1.xls

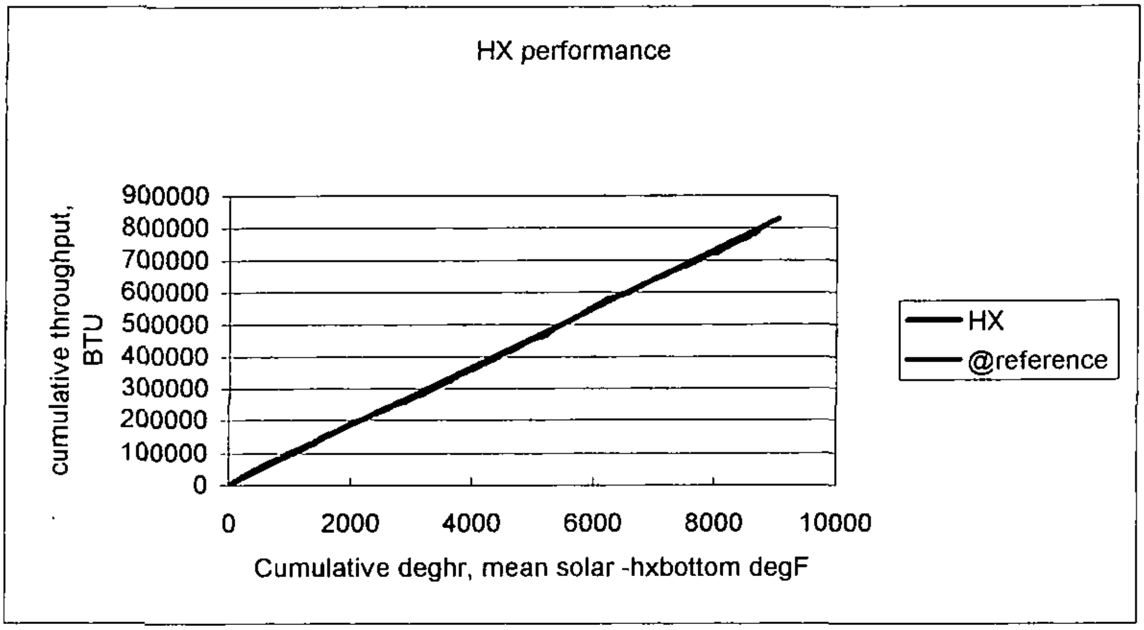
Begin	end
2-May-00	9-Jun-00
Month	May
Duration	37.9 days
Mean Inlet Temp	59.4 deg F
Mean Outlet Temp	92.0 deg F
Mean DHW usage	78.3 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	21,234 BTU/day
Solar Contribution	not monitored
HX Performance	91.34 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.97
Incident Solar	1156 BTU/ft2/day
Mean Efficiency	31%



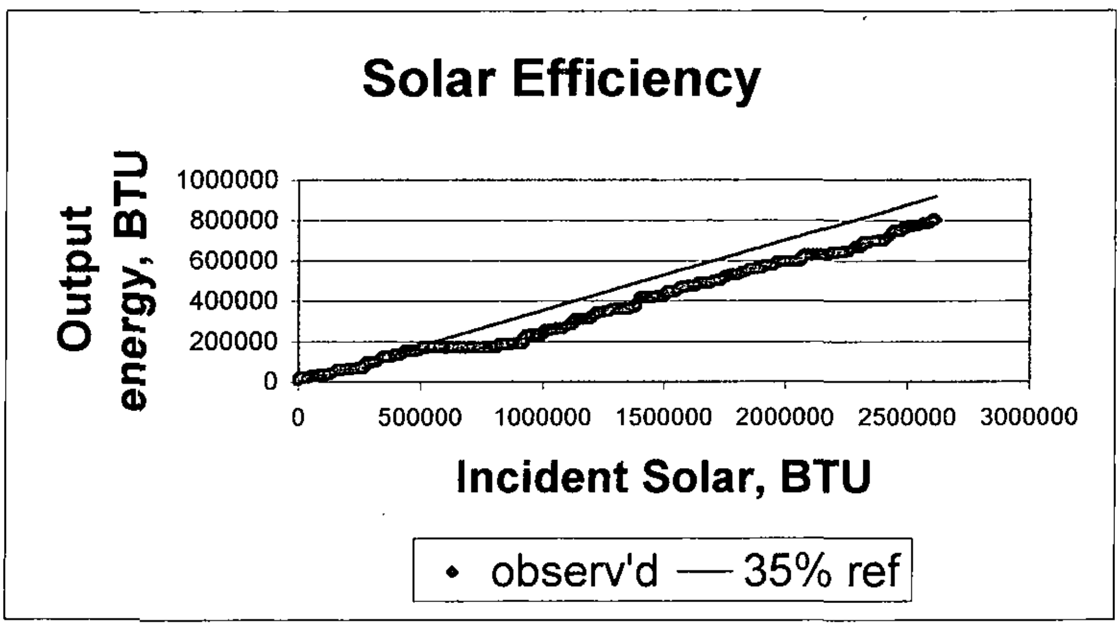
Typical DHW flow is approximately constant at 80 gallons/day. During days 10-15 usage is zero which lowers the period average.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident.



The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.

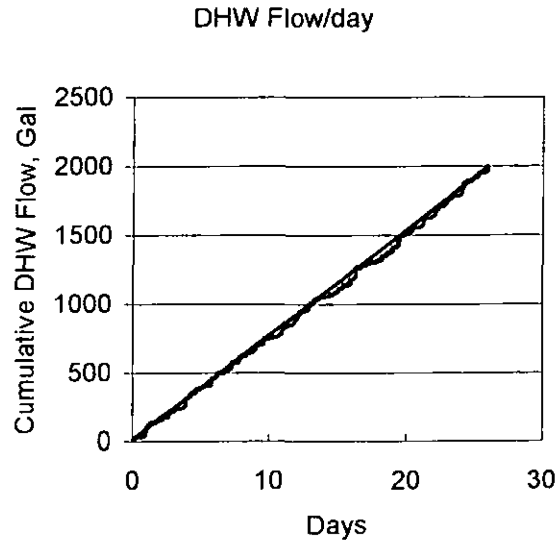


Solar efficiency is high, approximately 35% under full usage conditions. But a period of inactivity reduces the overall efficiency for the monitoring period.

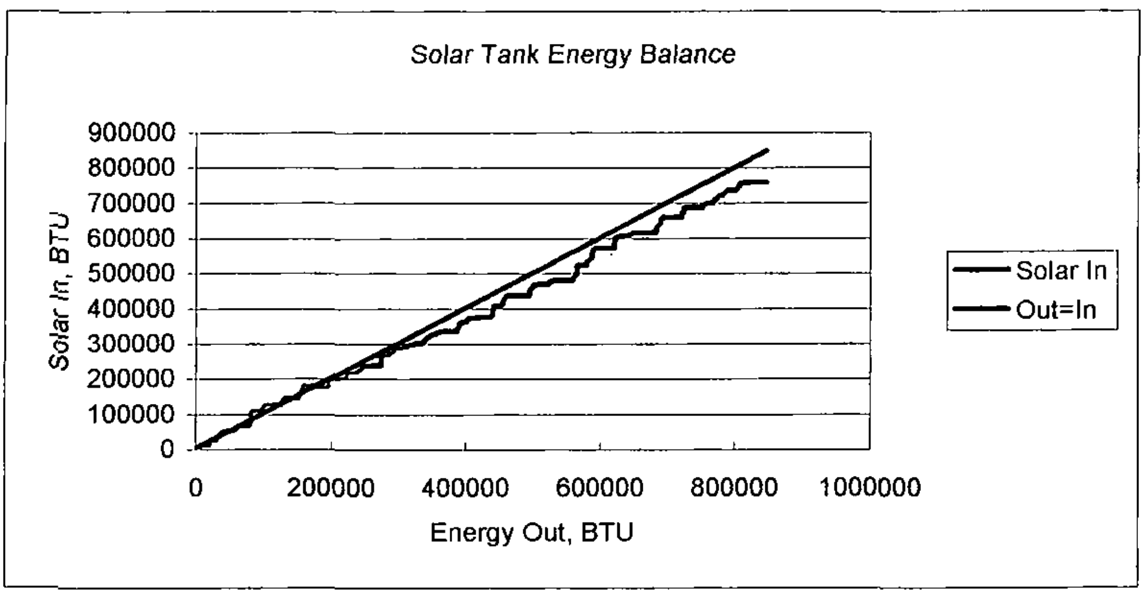
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer9f1.xls

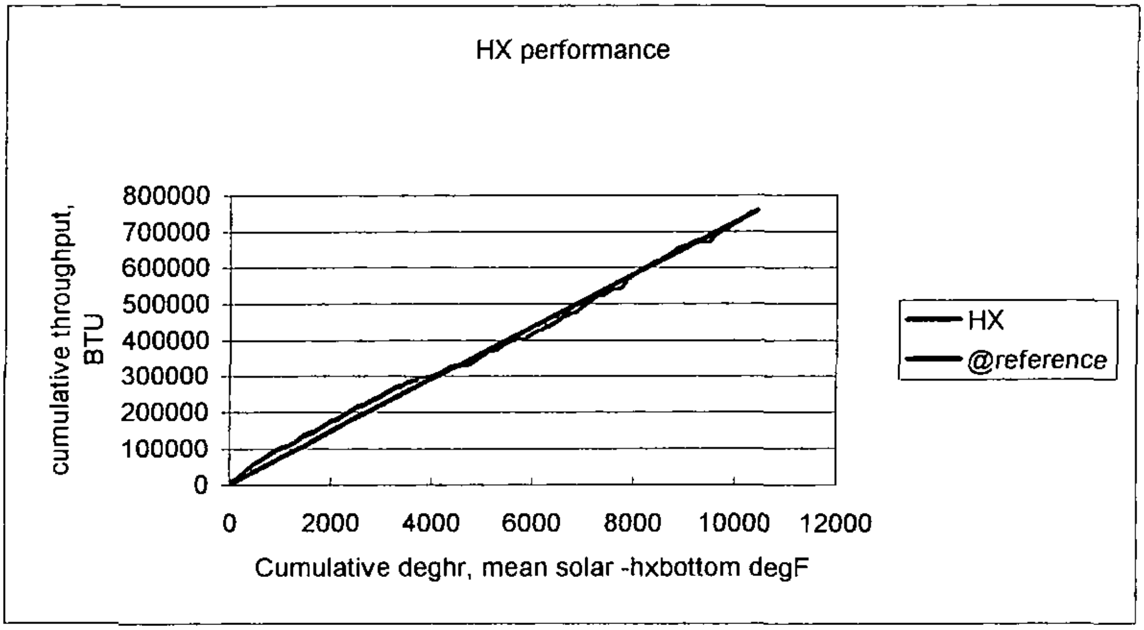
Begin	end
9-Jun-00	5-Jul-00
Month	*Jun*
Duration	26.0 days
Mean Inlet Temp	59.1 deg F
Mean Outlet Temp	110.1 deg F
Mean DHW usage	76.7 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	32,606 BTU/day
Solar Contribution	not monitored
HX Performance	72.39 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	1.12
Incident Solar	1721 BTU/ft2/day
Mean Efficiency	32%



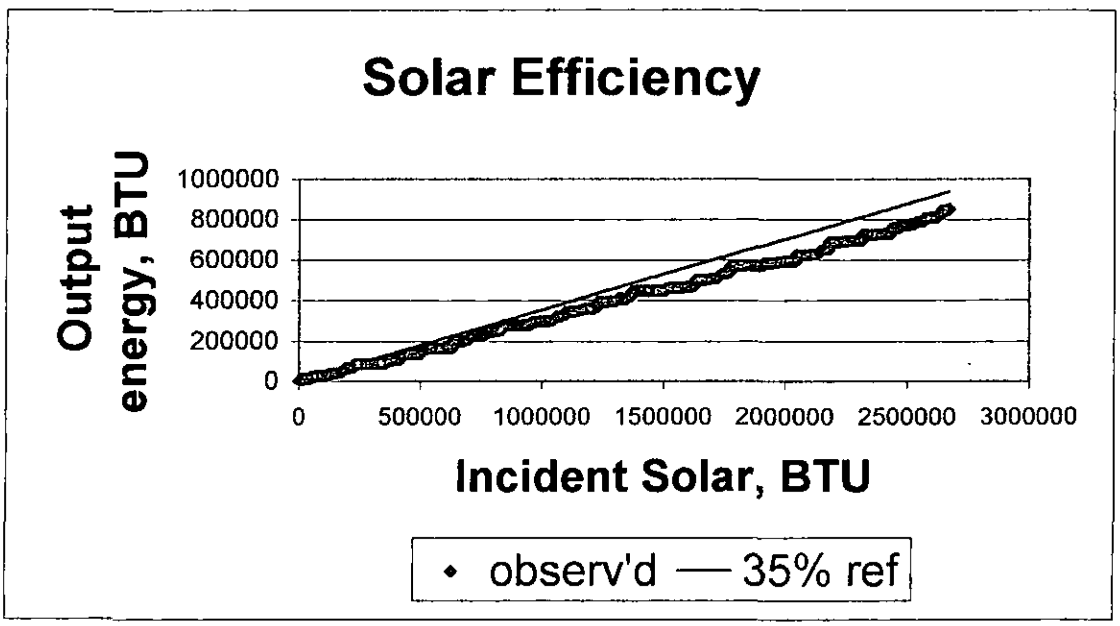
Typical DHW flow is approximately constant at 80 gallons/day.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident. Under these circumstances it is unlikley that more energy comes out of the tank than is input as indicated by the tank factor greater than 1. The most likley explanation is that the viscosity of the fluid is reduced and the pumping is faster th*a*
indicated in the model.



The HX performance is consistent with the improved performance of the replacement heat exchanger. HX performance should be increased by a factor of 1.13, the tank factor to represent the greater pump flows.

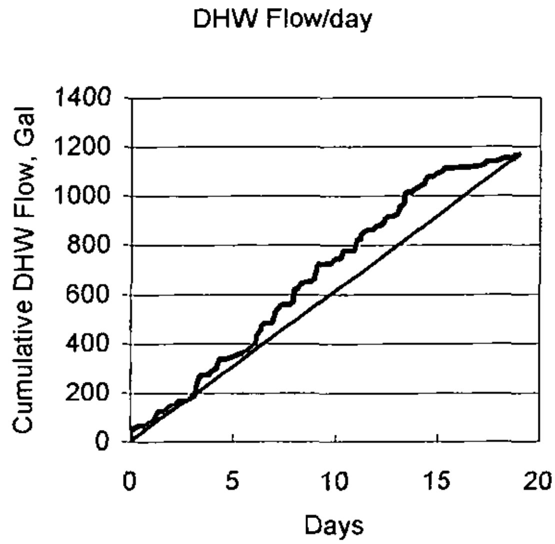


Solar efficiency is high, approximately 32% under full usage conditions.

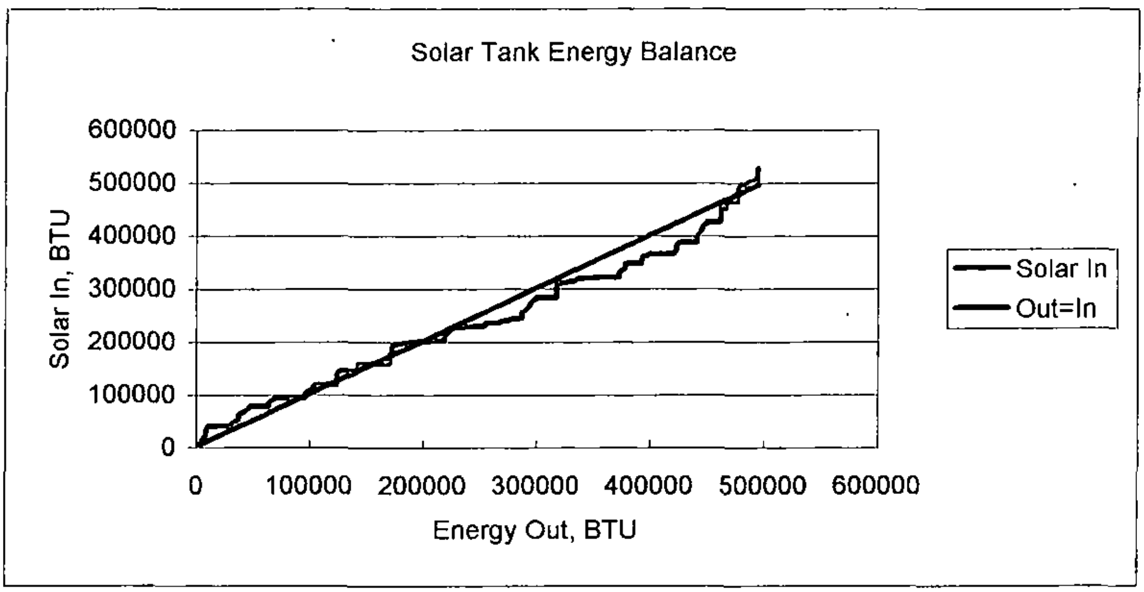
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer10f.xls

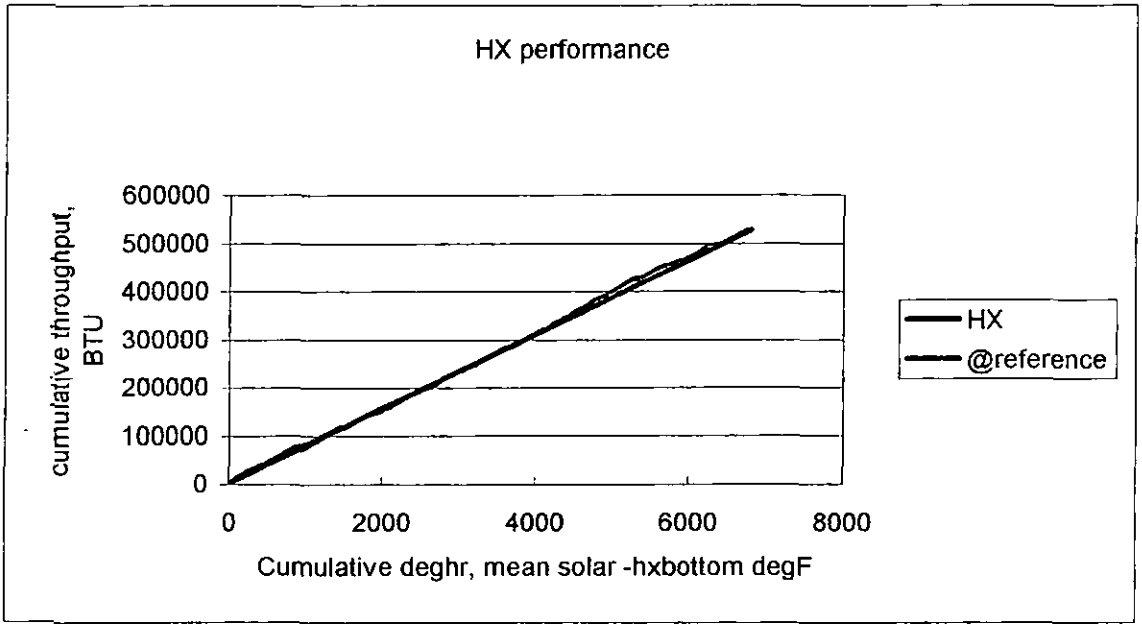
Begin	end
5-Jul-00	24-Jul-00
Month	Jul
Duration	19.0 days
Mean Inlet Temp	59.2 deg F
Mean Outlet Temp	110.1 deg F
Mean DHW usage	61.4 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	26,066 BTU/day
Solar Contribution	not monitored
HX Performance	77.31 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	0.94
Incident Solar	1661 BTU/ft2/day
Mean Efficiency	*26%*



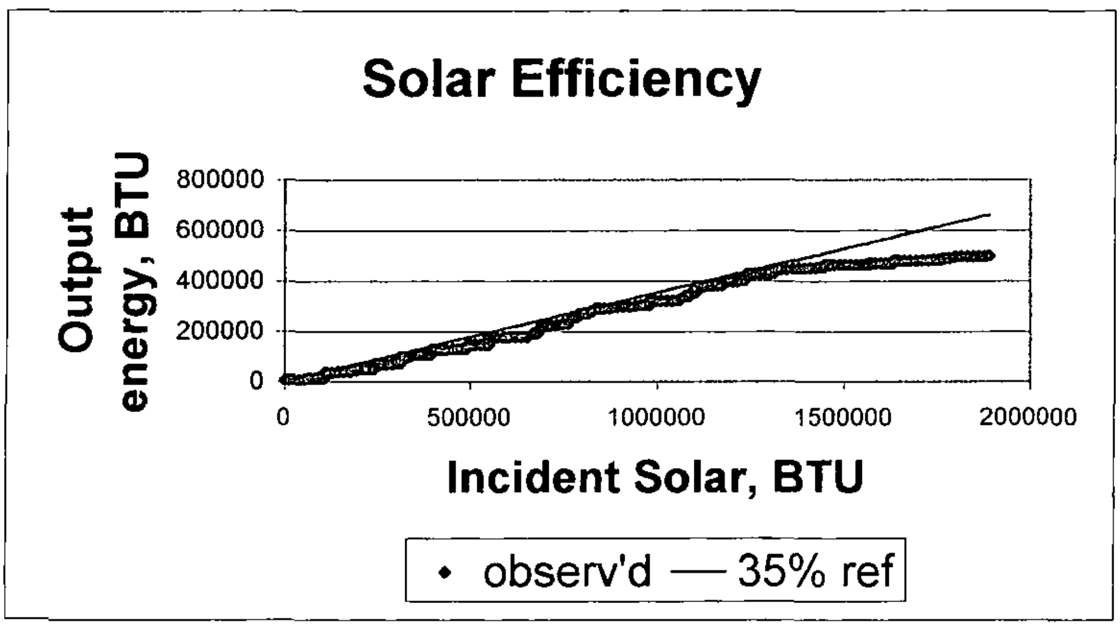
Typical DHW flow is approximately constant at 80 gallons/day. At the end of the monitoring period there is a usage rate of only about 20 gallons/day for about five days.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident. The increase in solar tank losses evident in tl end of the monitoring period is caused by the diminished usage rate and the correspondingly high(standby temperatures and thermal losses.



The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.

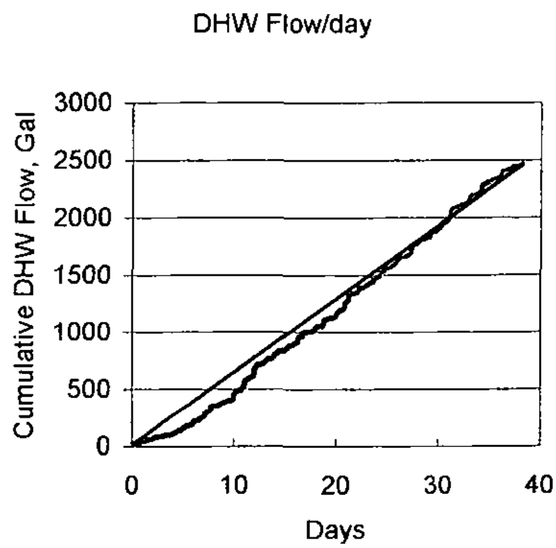


Solar efficiency is high, approximately 31% under full usage conditions. The reduced efficiency at t end of the monitoring period is due to reduced usage as occupancy was only 1 person for the last days. Under the lower usage, high sun conditions, the efficiency is reduced markedly to 10%.

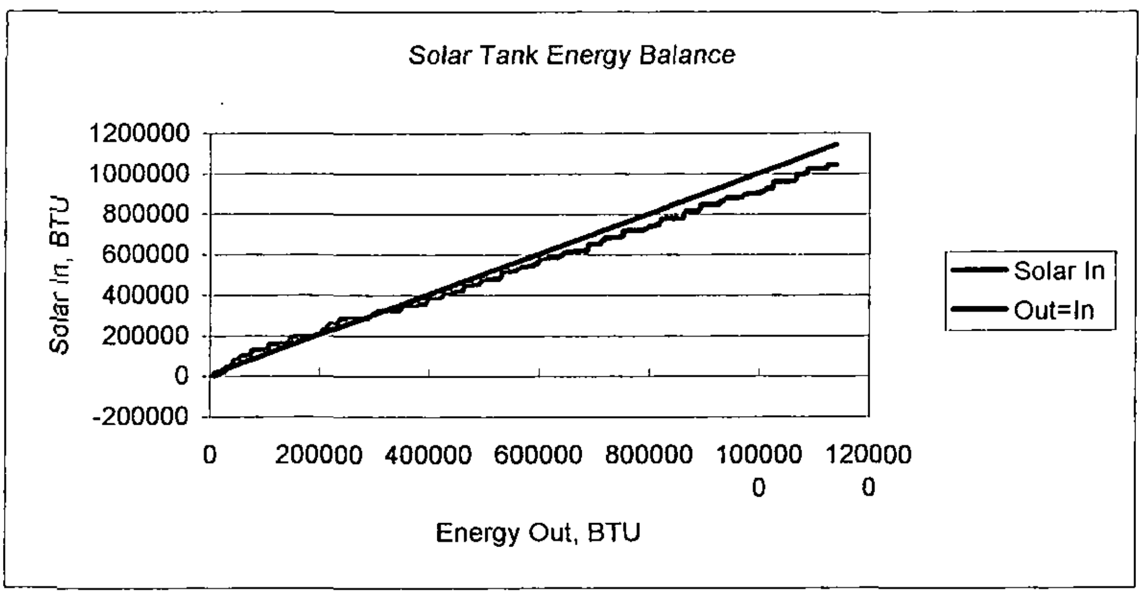
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer11f.xls

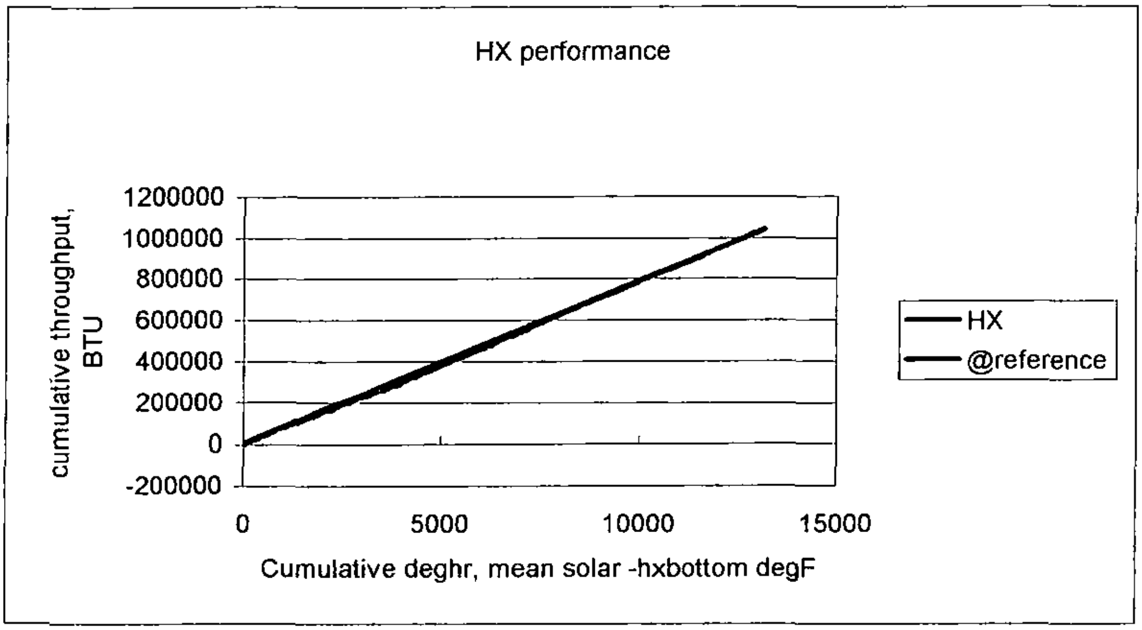
Begin	end
24-Jul-00	31-Aug-00
Month	Aug
Duration	38.3 days
Mean Inlet Temp	58.6 deg F
Mean Outlet Temp	114.3 deg F
Mean DHW usage	64.1 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	29,781 BTU/day
Solar Contribution	not monitored
HX Performance	78.73 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	1.10
Incident Solar	1670 BTU/ft2/day
Mean Efficiency	30%



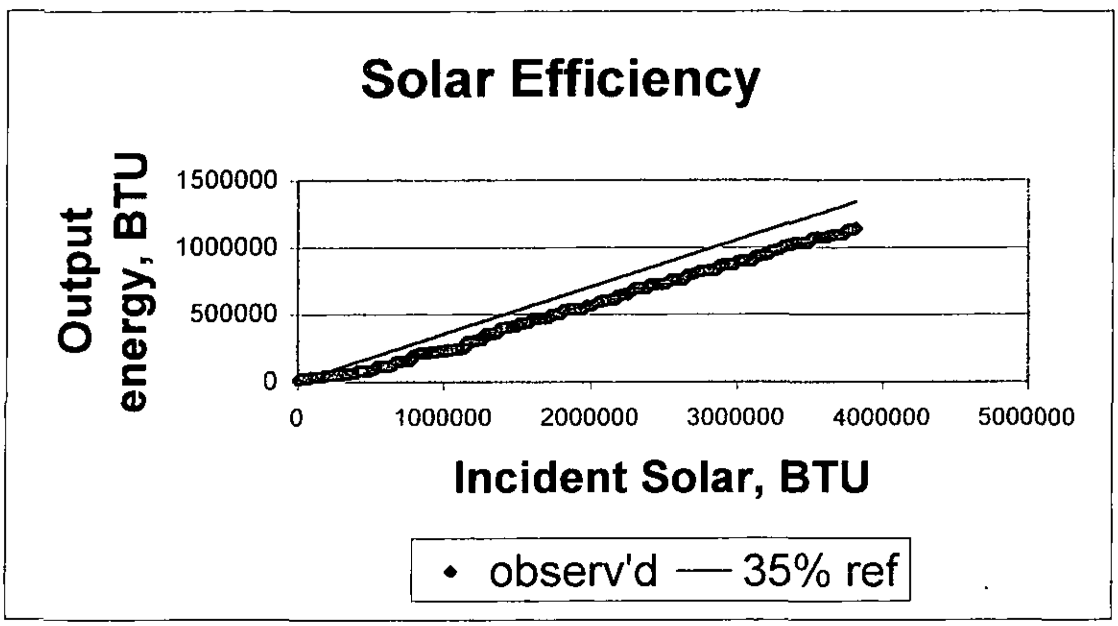
Typical DHW flow is approximately constant at 80 gallons/day. Low flow at the beginninng of the monitoring period lowers the mean flow.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident. Under these circumstances it is unlikley that more energy comes out of the tank than is input as indicated by the tank factor greater than 1. The most likley explanation is that the viscosity of the fluid is reduced and the pumping is faster th*a* *indicated in the model.*



The HX performance is consistent with the improved performance of the replacement heat exchanger. HX performance should be increased by a factor of 1.13, the tank factor to represent the greater pump flows.

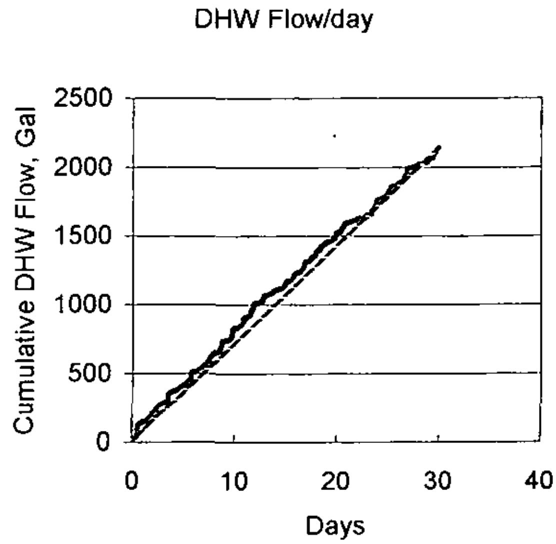


Solar efficiency is high, approximately 34% under full usage conditions. The reduced efficiency at t beginningof the monitoring period is due to reduced usage.

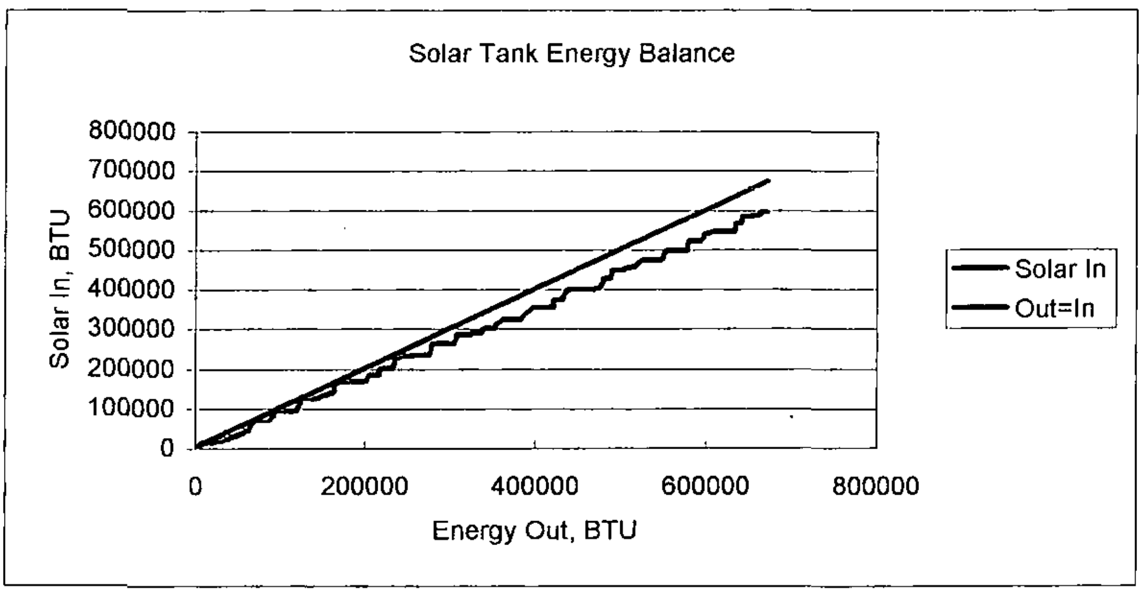
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer12f.xls

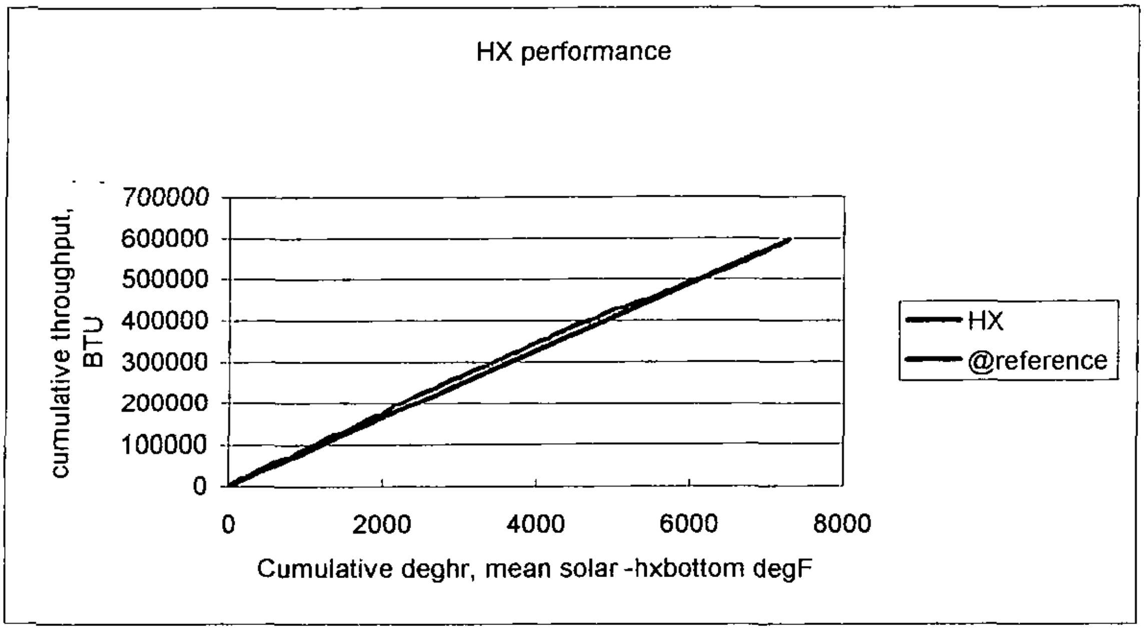
Begin	end
1-Sep-00	30-Sep-00
Month	Sep
Duration	30.0 days
Mean Inlet Temp	59.1 deg F
Mean Outlet Temp	96.9 deg F
Mean DHW usage	71.3 gal/day
Mean DHW BTU/day	not monitored
Mean Solar BTU/day	22,443 BTU/day
Solar Contribution	not monitored
HX Performance	81.45 BTU/deghr
DHW tank factor	not monitored
Solar tank factor	1.13
Incident Solar	1181 BTU/ft2/day
Mean Efficiency	32%



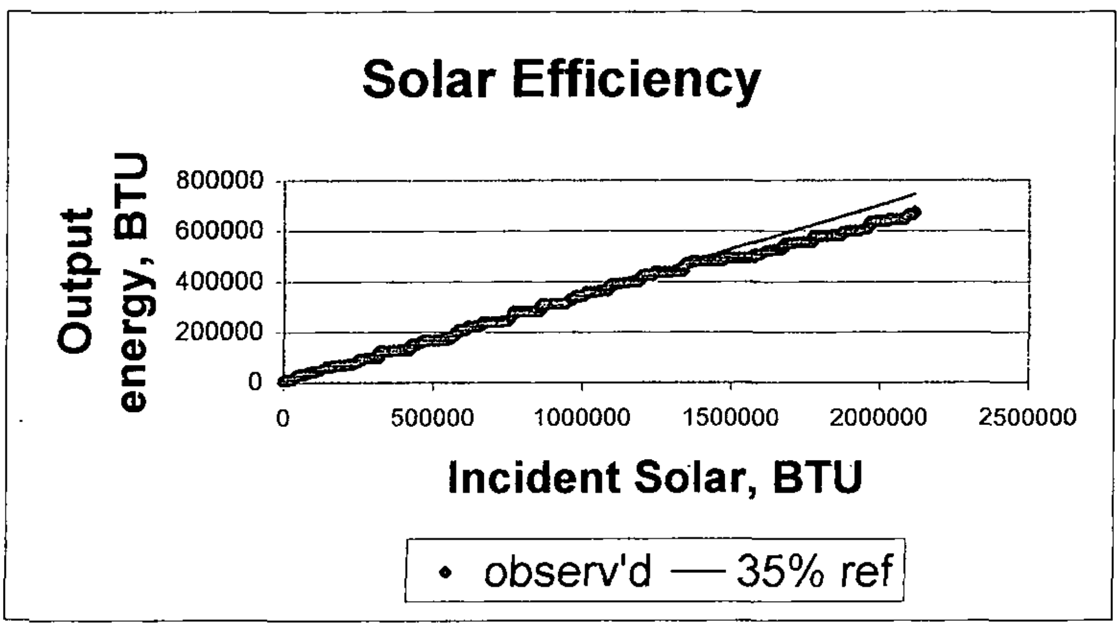
Typical DHW flow is approximately constant at 75 gallons/day.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident. Under these circumstances it is unlikley that more energy comes out of the tank than is input as indicated by the tank factor greater than 1. The most likley explanation is that the viscosity of the fluid is reduced and the pumping is faster th indicated in the model.



The HX performance is consistent with the improved performance of the replacement heat exchanger.

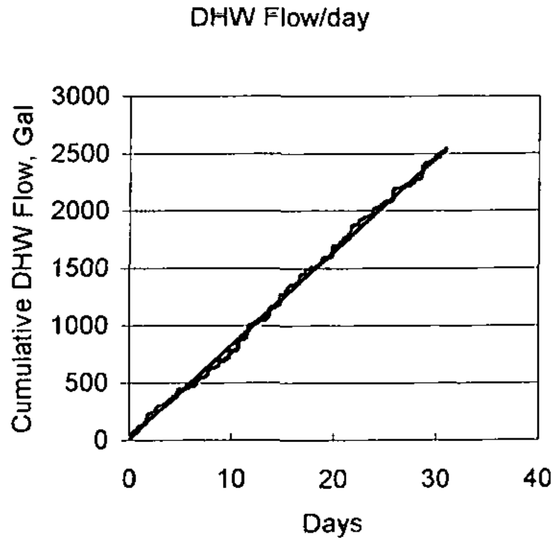


Solar efficiency is high, approximately 35% under full usage conditions at the beginning of the monitoring period. Efficiency appears to diminish with the lower sun near the end of the period.

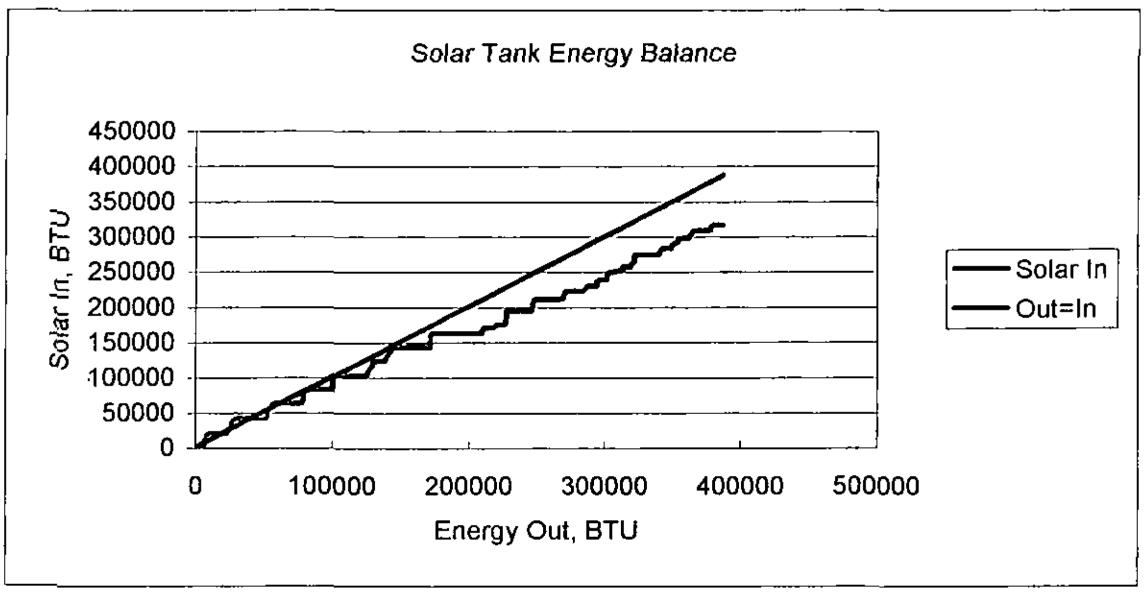
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer13f.xls

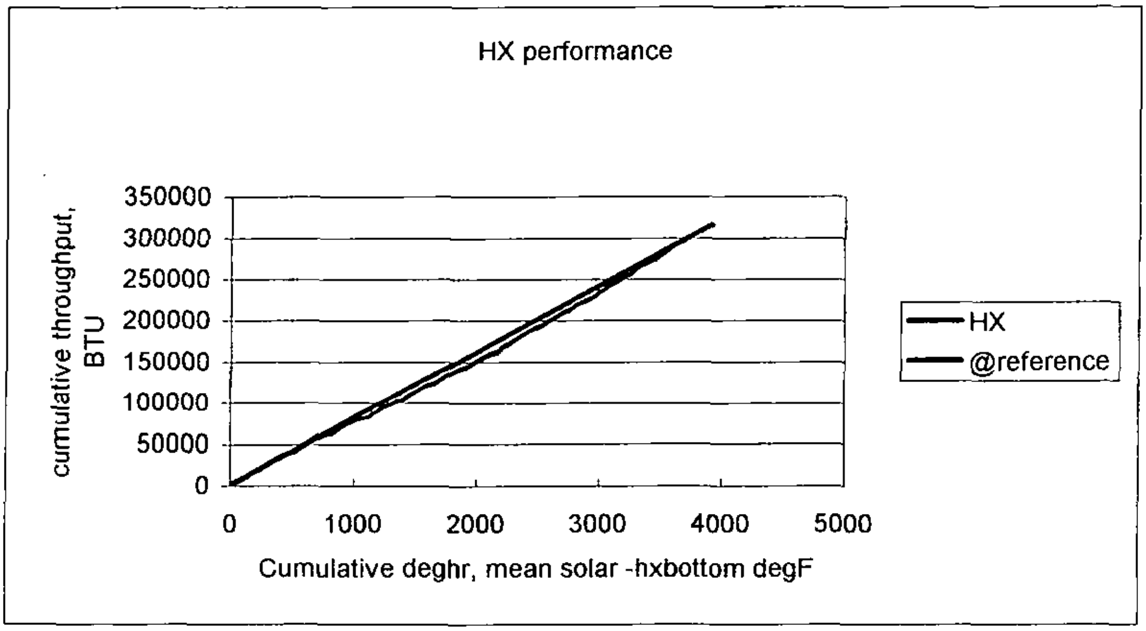
Begin	end	
1-Oct-00	31-Oct-00	
Month	Oct	
Duration	31.0	days
Mean Inlet Temp	57.3	deg F
Mean Outlet Temp	75.6	deg F
Mean DHW usage	82.0	gal/day
Mean DHW BTU/day	not monitored	
Mean Solar BTU/day	12,498	BTU/day
Solar Contribution	not monitored	
HX Performance	80.63	BTU/deghr
DHW tank factor	not monitored	
Solar tank factor	1.23	
Incident Solar	700	BTU/ft2/day
Mean Efficiency	30%	



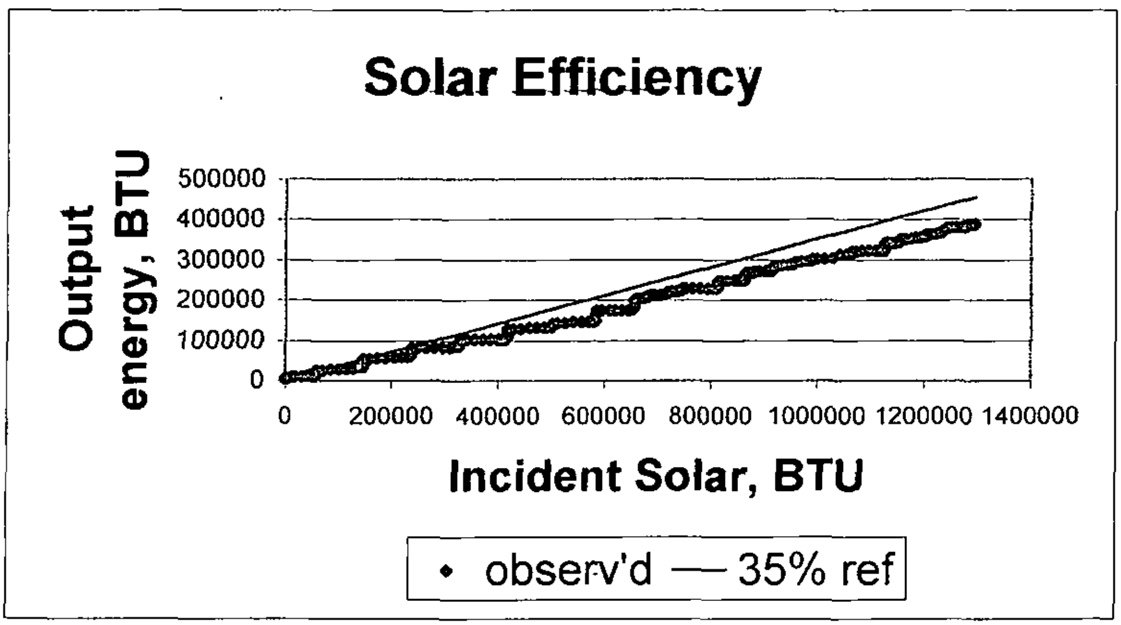
Typical DHW flow is approximately constant at 80 gallons/day. At the end of the monitoring period there is a usage rate of only about 20 gallons/day for about five days.



Solar input is significant for most of the monitoring period. The solar tank is losing energy when it is significantly warmer than its surroundings. The solar tank appears to be retaining its energy during the night; no serious night losses are evident. The lack of solar input in the middle of the period is due to a prolonged cloudy spell. Solar gain may be under reported during this time.



The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.

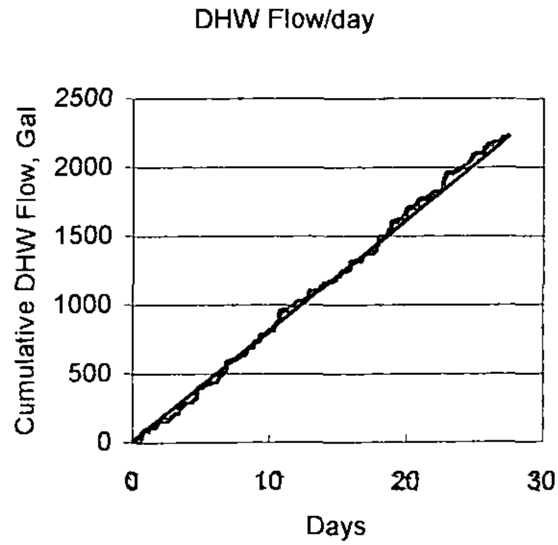


Solar efficiency is high, approximately 31% under full usage conditions.

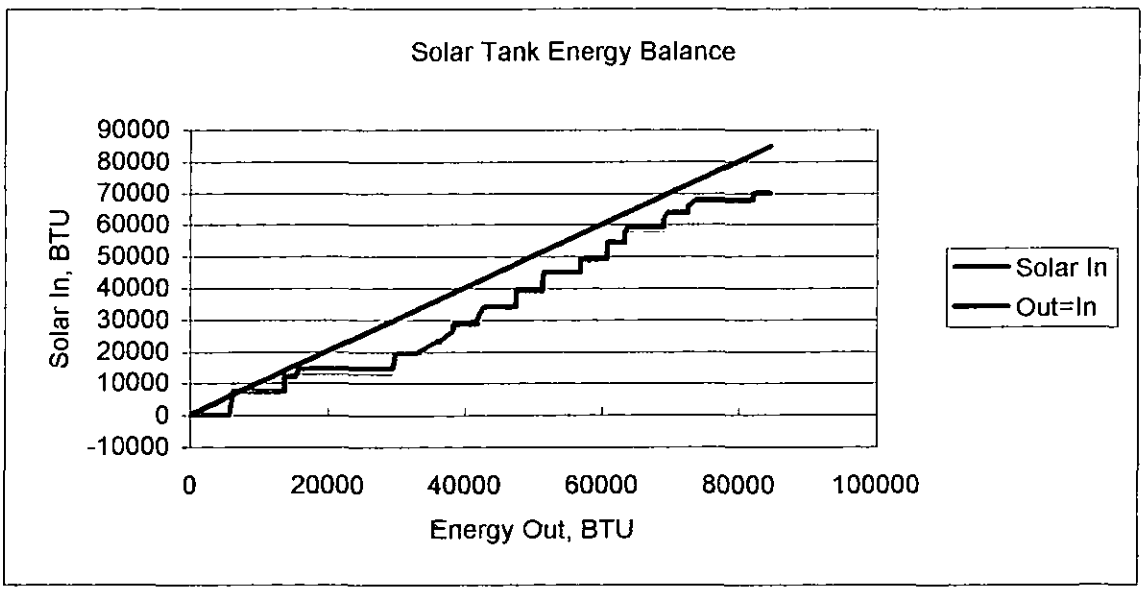
SOLAR DHW SYSTEM MONITORING SUMMARY

System: DHW1- lemer14f.xls

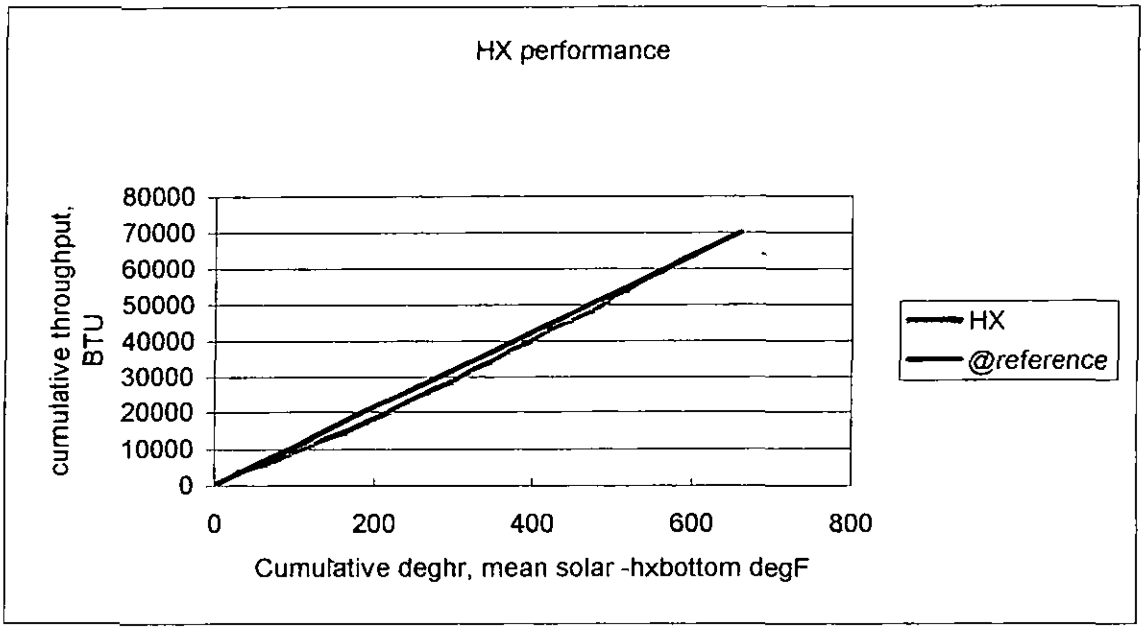
Begin	end	
1-Nov-00	28-Nov-00	
Month	Nov	
Duration	27.6	days
Mean Inlet Temp	55.9	deg F
Mean Outlet Temp	60.4	deg F
Mean DHW usage	80.6	gal/day
Mean DHW BTU/day	not monitored	
Mean Solar BTU/day	3,073	BTU/day
Solar Contribution	not monitored	
HX Performance	105.58	BTU/deghr
DHW tank factor	not monitored	
Solar tank factor	1.21	
Incident Solar	250	BTU/ft2/day
Mean Efficiency	21%	



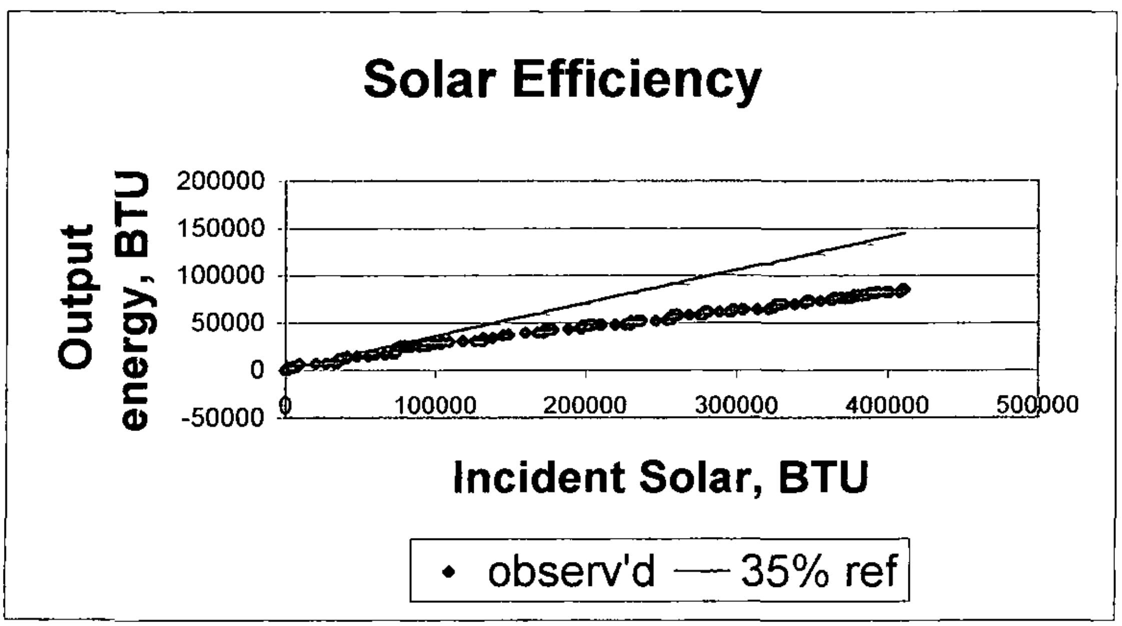
Typical DHW flow is approximately constant at 80 gallons/day.



Solar input is not significant for most of the monitoring period. The solar tank is gaining energy fror surroundings for most of the monitoring period and making it appear that more energy is exiting th than is input by solar leading to the tank factor greater than 1.



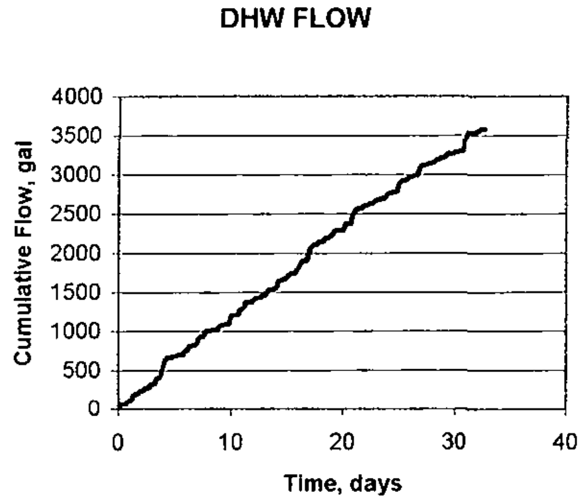
The HX performance is consistent with the improved performance of the replacement heat exchanger. There appears to be no change in HX performance due to the reduced DHW usage.

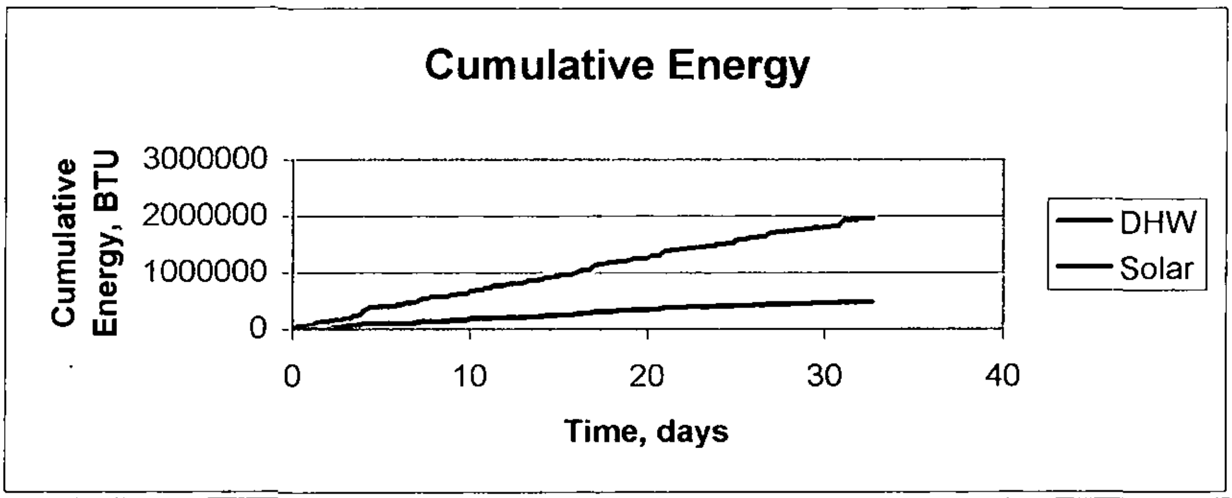


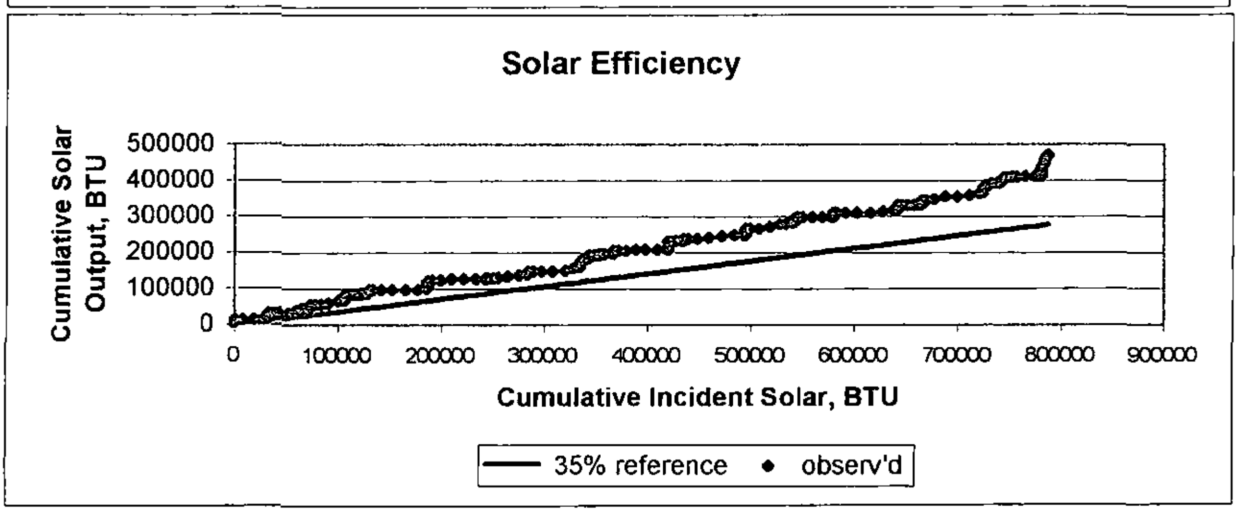
Solar efficiency is low, approximately 21% under full usage conditions. The reduced efficiency at tl end of the monitoring pèriod is due to reduced usage as occupancy was only 1 person for the last

SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont5aa.xls

Start date	end date	
29-Dec-99	31-Jan-00	
Month	Jan	
Duration	32.71	days
Mean Inlet Temp	44.3	deg F
Mean Outlet Temp	109.8	deg F
Mean DHW usage	109.6	gal/day
Mean DHW BTU/day	59,809	BTU/day
Mean Solar BTU/day	14,370	BTU/day
Solar Contribution	24%	
HX Performance	401	BTU/deghr
DHW tank factor	0.83	
Solar tank factor	1.15	
Incident Solar	403	BTU/ft2/da
Mean Efficiency	52%	
Electric standby	12,070	BTU/day

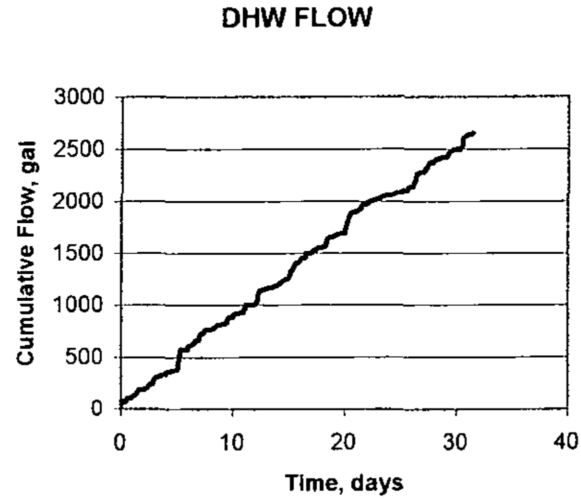


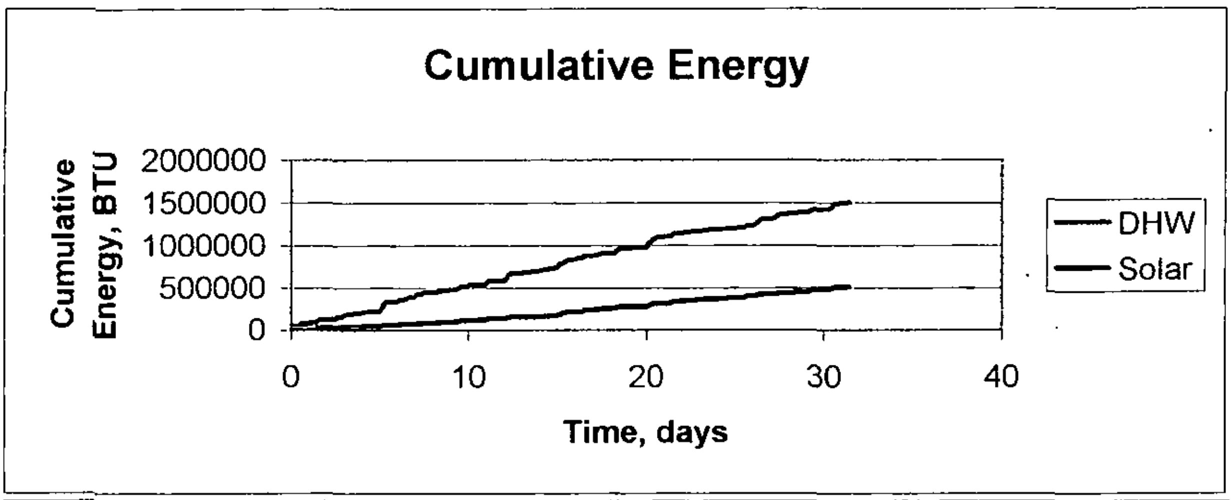


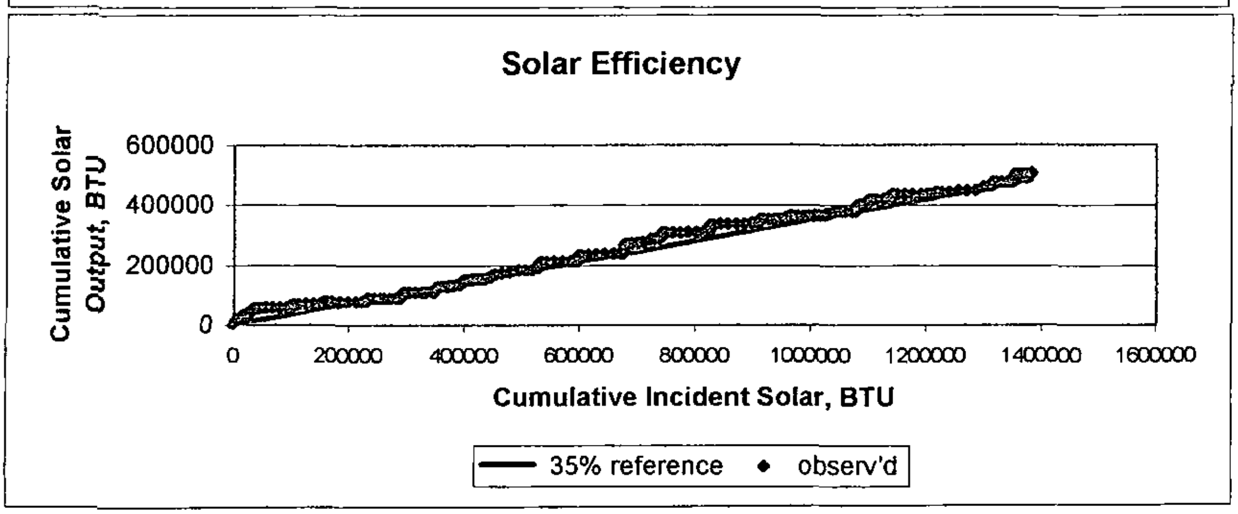


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont5aa.xls

Start date	end date	
31-Jan-00	02-Mar-00	
Month	Feb	
Duration	31.46	days
Mean Inlet Temp	42.6	deg F
Mean Outlet Temp	110.5	deg F
Mean DHW usage	84.3	gal/day
Mean DHW BTU/day	47,725	BTU/day
Mean Solar BTU/day	16,168	BTU/day
Solar Contribution	34%	
HX Performance	311	BTU/deghr
DHW tank factor	0.82	
Solar tank factor	0.88	
Incident Solar	736	BTU/ft2/da
Mean Efficiency	42%	
Electric standby	10,650	BTU/day

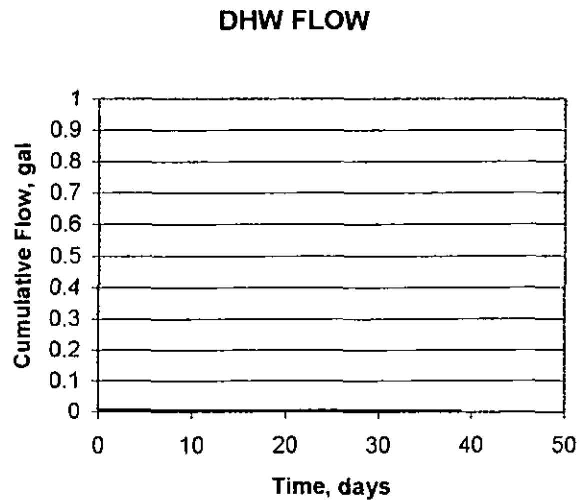


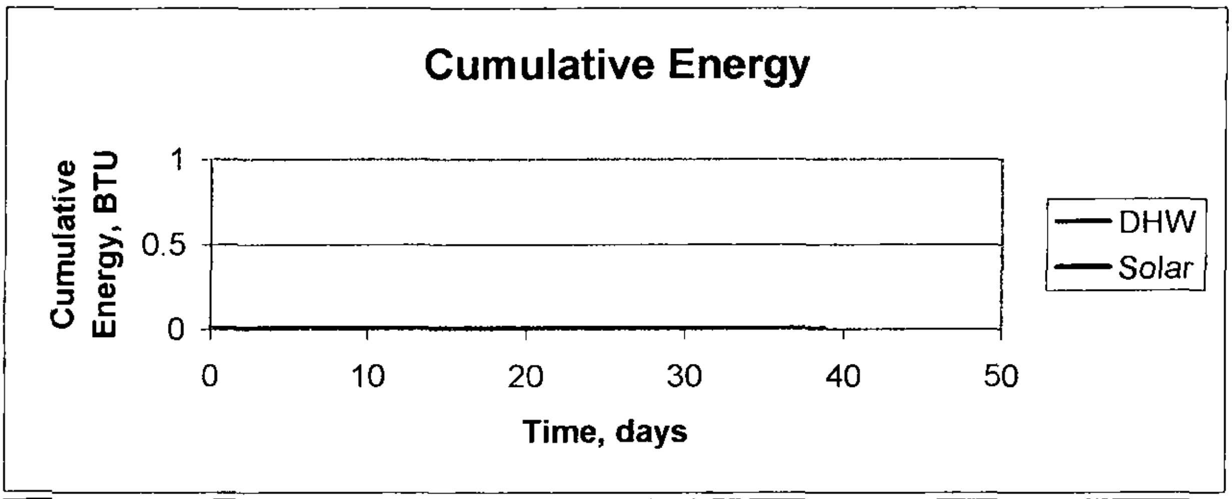


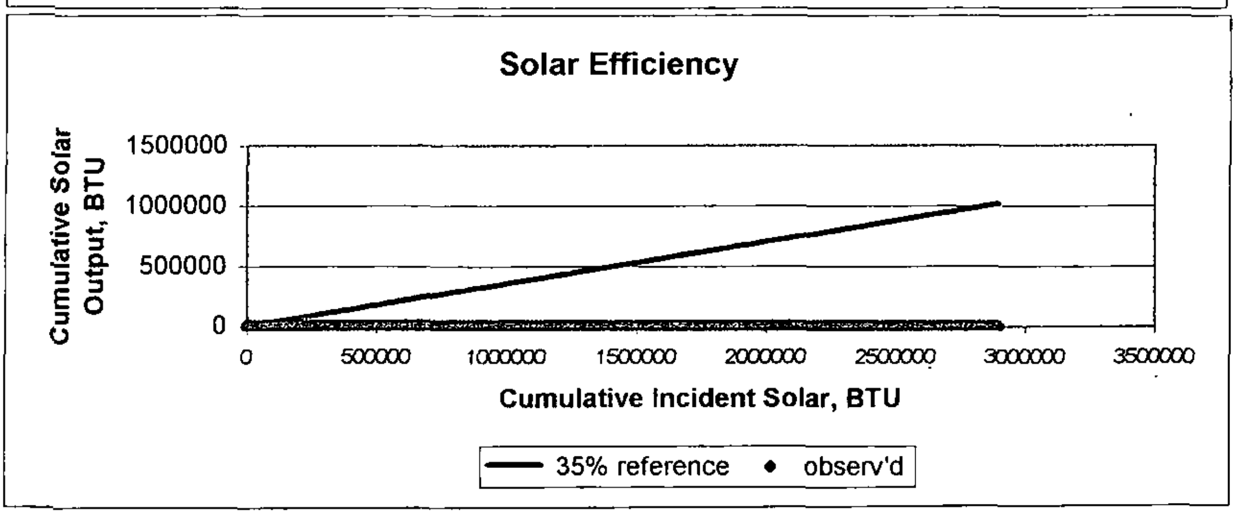


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont6aa.xls

Start date	end date	
03-Mar-95	11-Apr-95	
Month	Mar	
Duration	38.92	days
Mean Inlet Temp	#DIV/0!	deg F
Mean Outlet Temp	#DIV/0!	deg F
Mean DHW usage	0.0	gal/day
Mean DHW BTU/day	0	BTU/day
Mean Solar BTU/day	0	BTU/day
Solar Contribution	#DIV/0!	
HX Performance	191	BTU/deghr
DHW tank factor	0.00	
Solar tank factor	0.00	
Incident Solar	1,246	BTU/ft2/da
Mean Efficiency	42%	
Electric standby	34,873	BTU/day

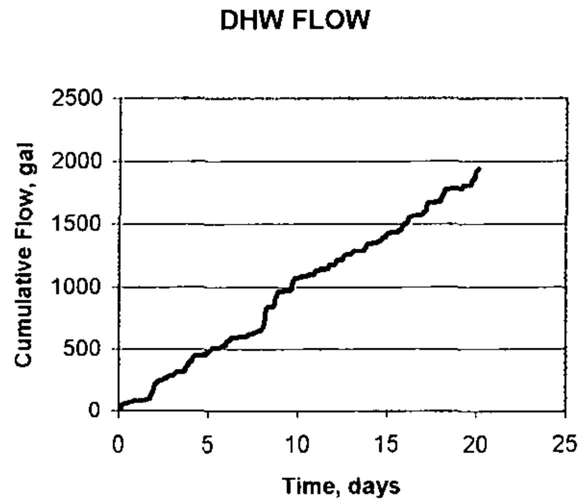


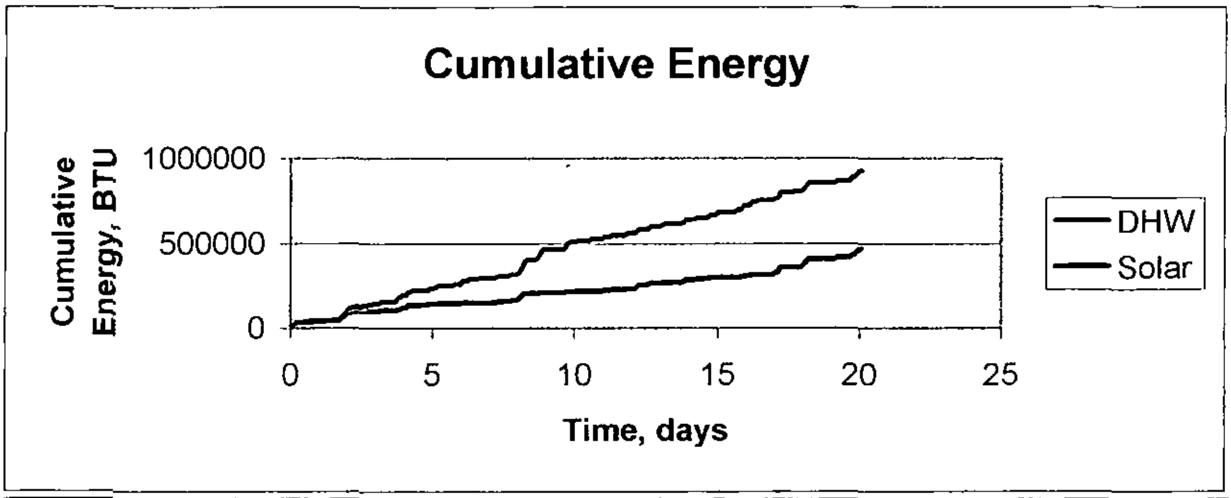


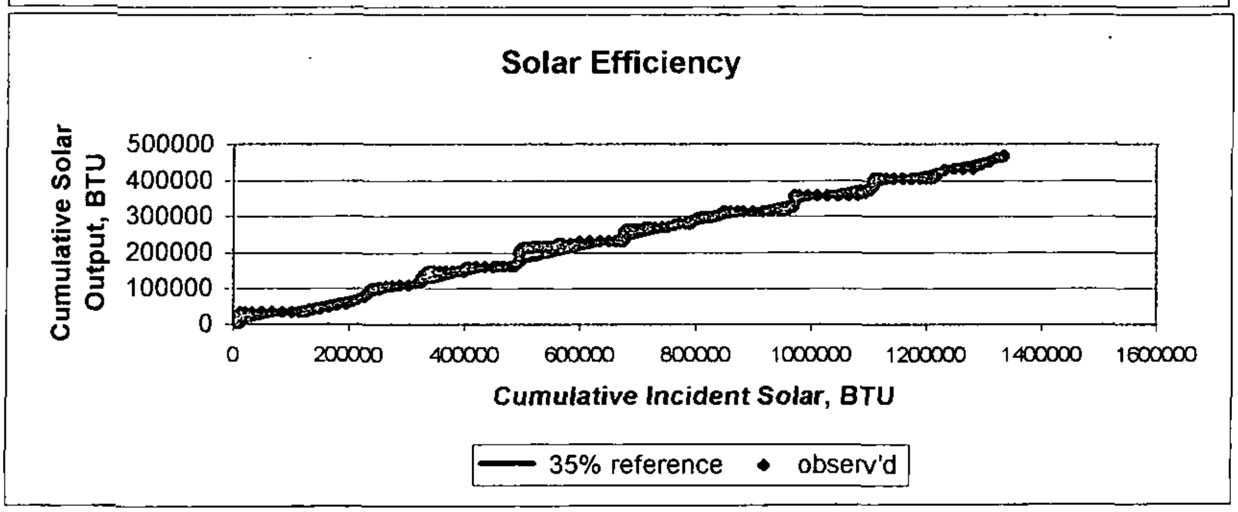


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont7a.xls

Start date	end date	
13-Apr-00	03-May-00	
Month	Apr	
Duration	20.13	days
Mean Inlet Temp	52.3	deg F
Mean Outlet Temp	109.7	deg F
Mean DHW usage	96.5	gal/day
Mean DHW BTU/day	46,186	BTU/day
Mean Solar BTU/day	23,272	BTU/day
Solar Contribution	50%	
HX Performance	162	BTU/deghr
DHW tank factor	0.83	
Solar tank factor	0.97	
Incident Solar	1,110	BTU/ft2/da
Mean Efficiency	36%	
Electric standby	9,750	BTU/day

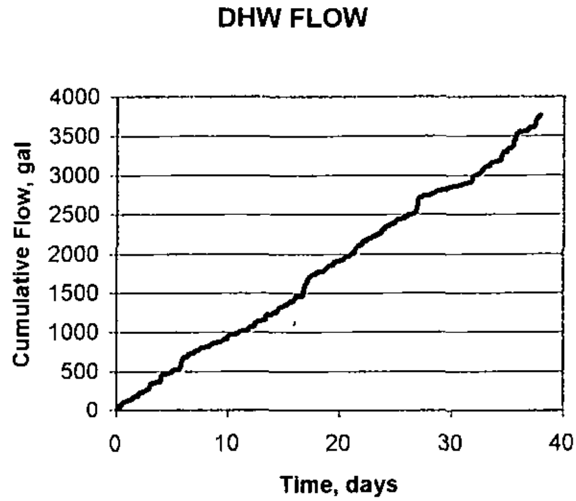


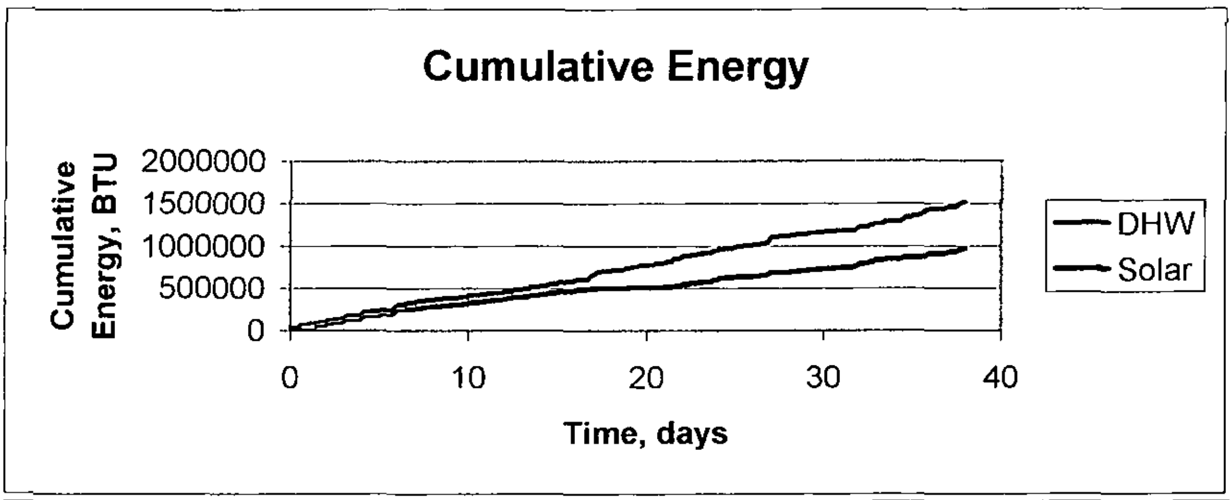


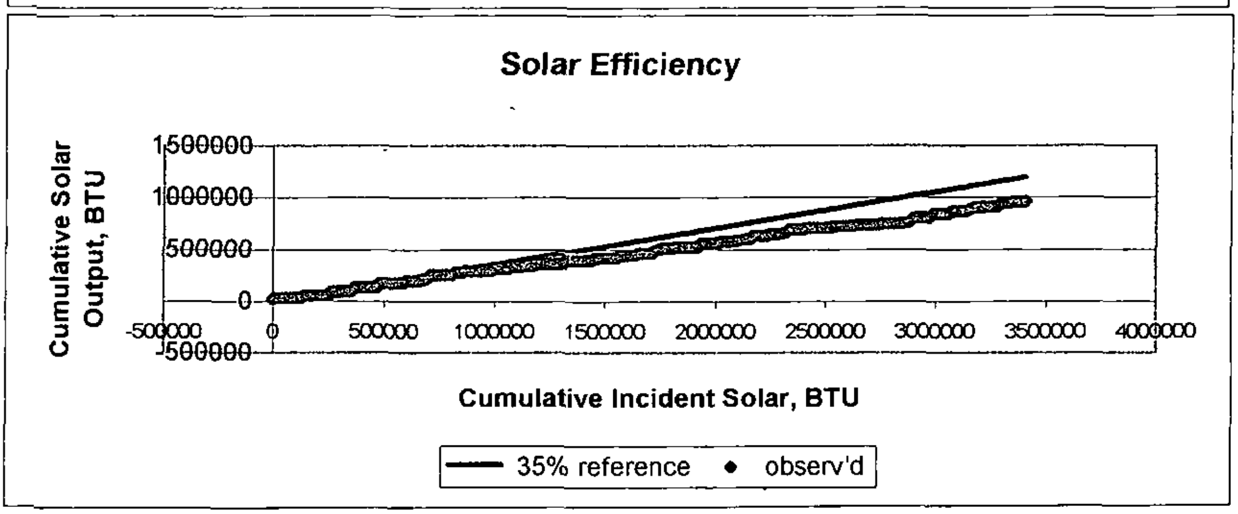


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont8a.xls

Start date	end date	
03-May-00	10-Jun-00	
Month	May	
Duration	38.04	days
Mean Inlet Temp	62.2	deg F
Mean Outlet Temp	110.3	deg F
Mean DHW usage	98.9	gal/day
Mean DHW BTU/day	39,686	BTU/day
Mean Solar BTU/day	25,229	BTU/day
Solar Contribution	64%	
HX Performance	120	BTU/deghr
DHW tank factor	0.85	
Solar tank factor	0.84	
Incident Solar	1,501	BTU/ft2/da
Mean Efficiency	33%	
Electric standby	7,243	BTU/day

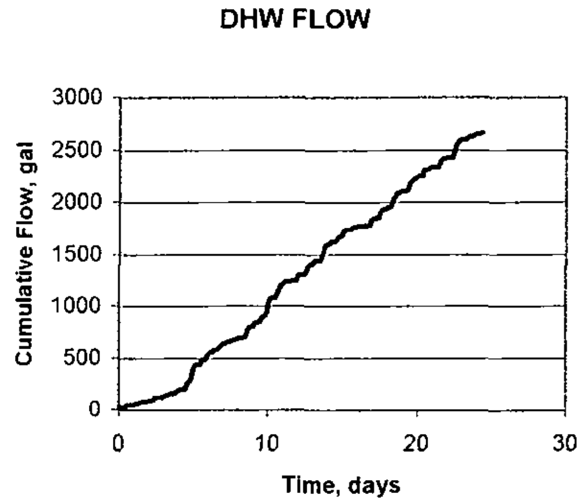


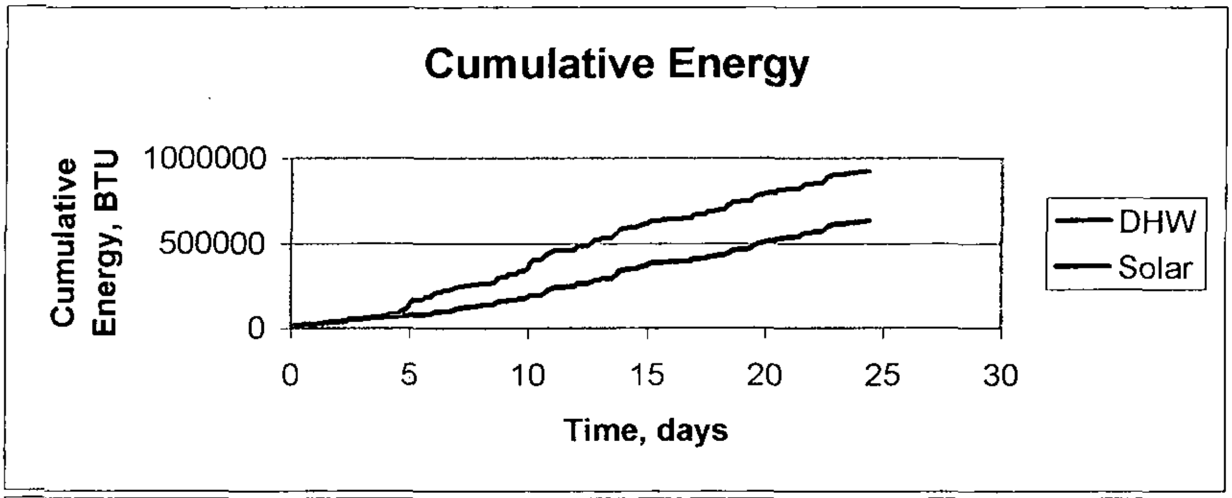


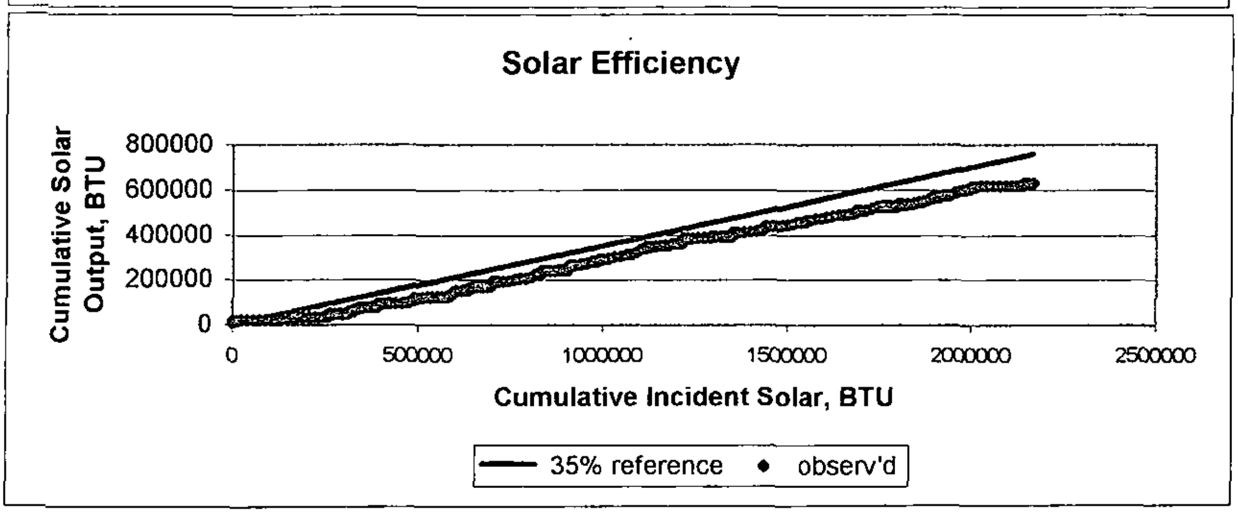


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont9a.xls

Start date	end date	
10-Jun-00	06-Jul-00	
Month	Jun	
Duration	24.42	days
Mean Inlet Temp	69.0	deg F
Mean Outlet Temp	110.5	deg F
Mean DHW usage	109.0	gal/day
Mean DHW BTU/day	37,698	BTU/day
Mean Solar BTU/day	25,757	BTU/day
Solar Contribution	68%	
HX Performance	128	BTU/deghr
DHW tank factor	0.86	
Solar tank factor	0.90	
Incident Solar	1,486	BTU/ft2/da
Mean Efficiency	32%	
Electric standby	6,256	BTU/day

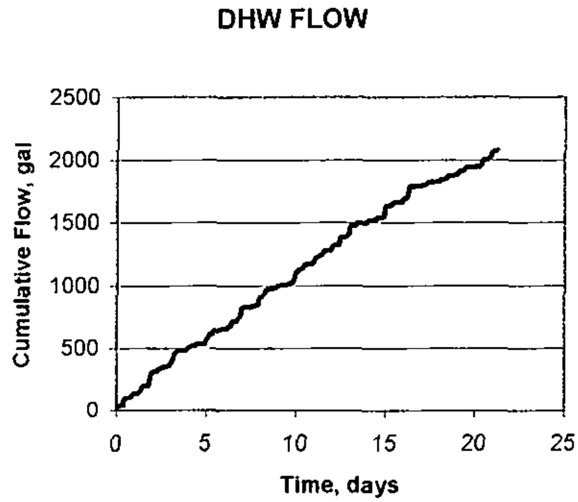


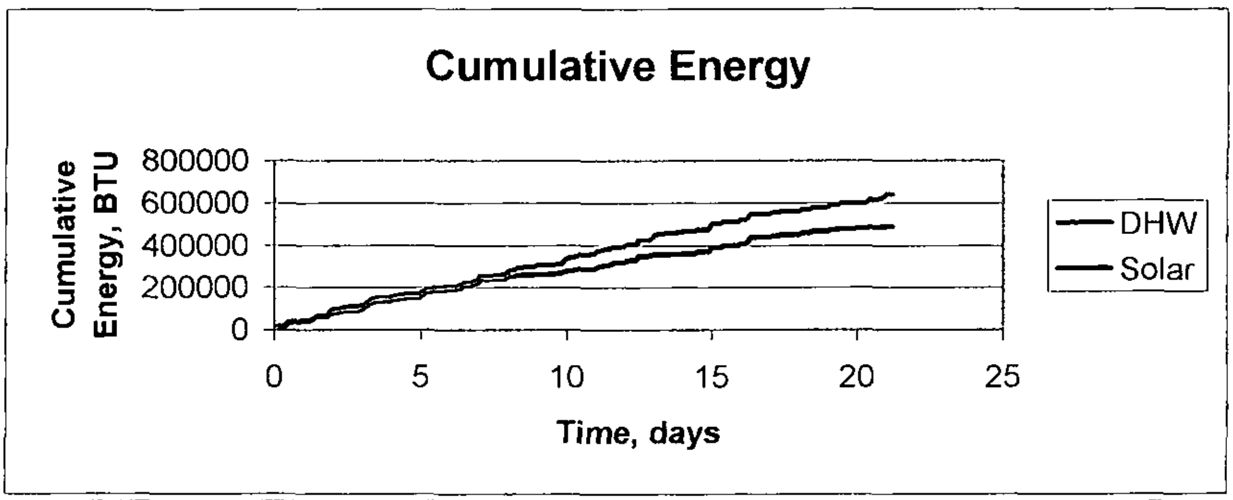


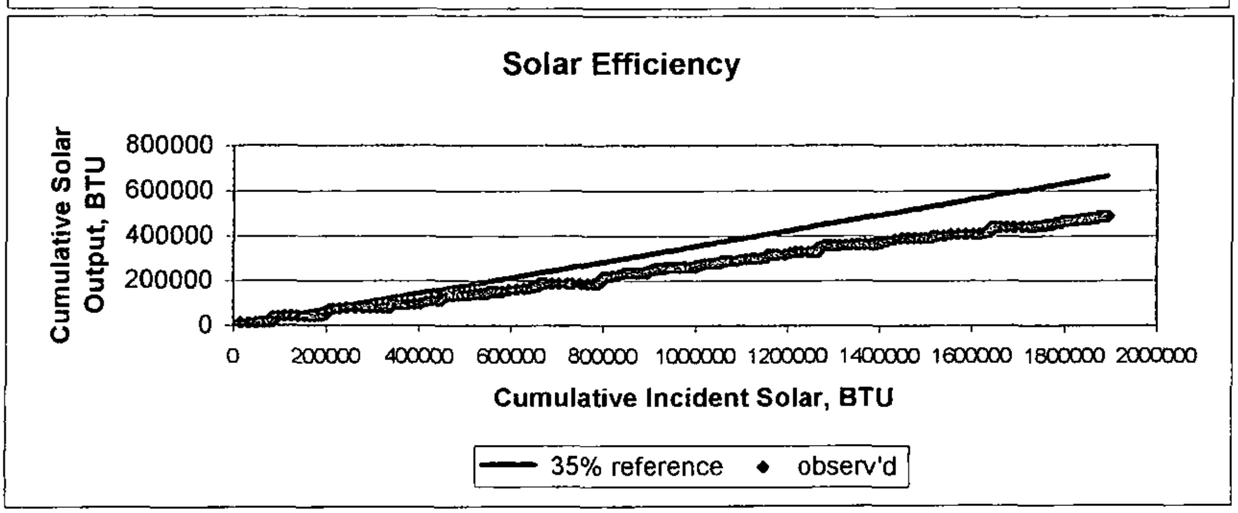


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont10a.xls

Start date	end date	
06-Jul-00	27-Jul-00	
Month	Jul	
Duration	21.25	days
Mean Inlet Temp	73.8	deg F
Mean Outlet Temp	110.7	deg F
Mean DHW usage	97.6	gal/day
Mean DHW BTU/day	30,013	BTU/day
Mean Solar BTU/day	22,822	BTU/day
Solar Contribution	76%	
HX Performance	104	BTU/deghr
DHW tank factor	0.86	
Solar tank factor	0.92	
Incident Solar	1,492	BTU/ft2/da
Mean Efficiency	28%	
Electric standby	5,055	BTU/day

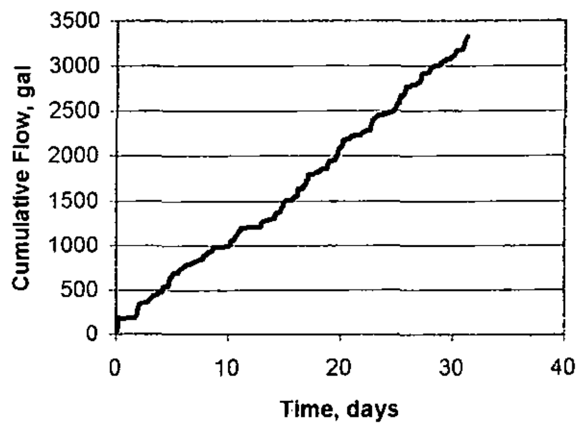


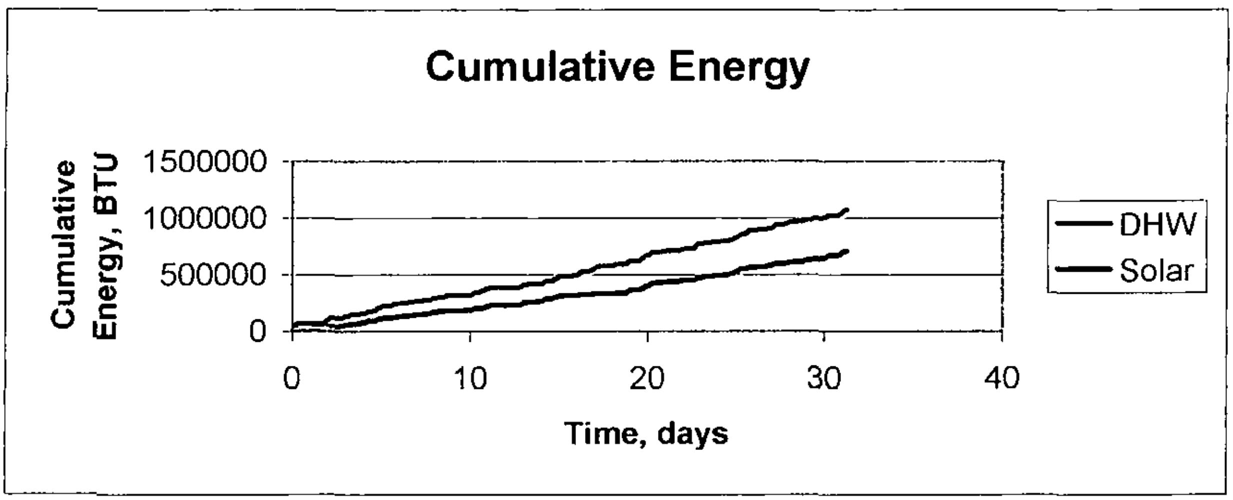


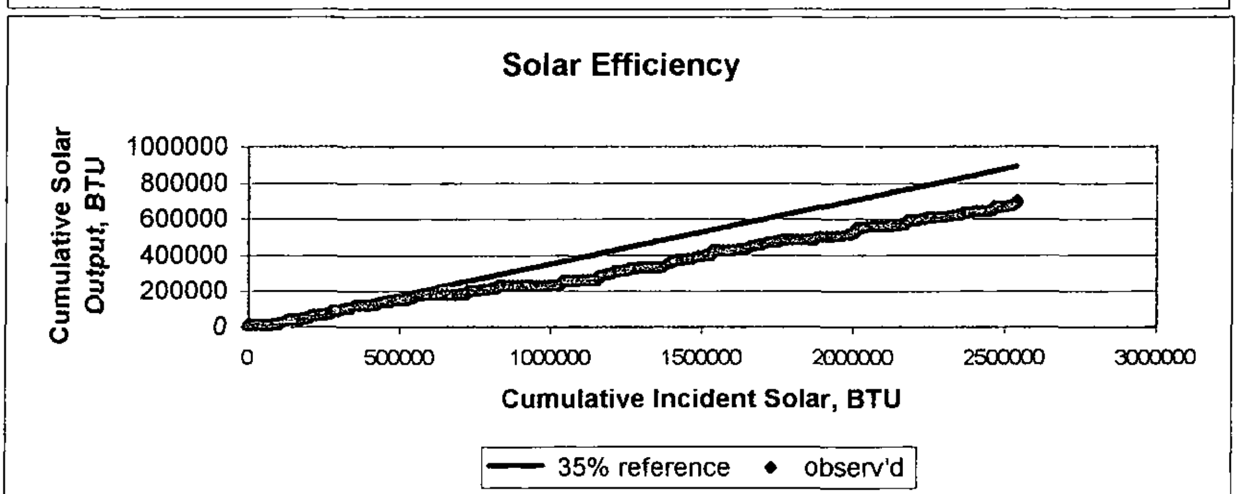


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont11a.xls

Start date	end date	
27-Jul-00	28-Aug-00	
Month	Aug	
Duration	31.29	days
Mean Inlet Temp	72.5	deg F
Mean Outlet Temp	111.0	deg F
Mean DHW usage	106.4	gal/day
Mean DHW BTU/day	34,163	BTU/day
Mean Solar BTU/day	22,376	BTU/day
Solar Contribution	65%	
HX Performance	120	BTU/deghr
DHW tank factor	0.85	
Solar tank factor	1.00	
Incident Solar	1,357	BTU/ft2/da
Mean Efficiency	28%	
Electric standby	6,173	BTU/day

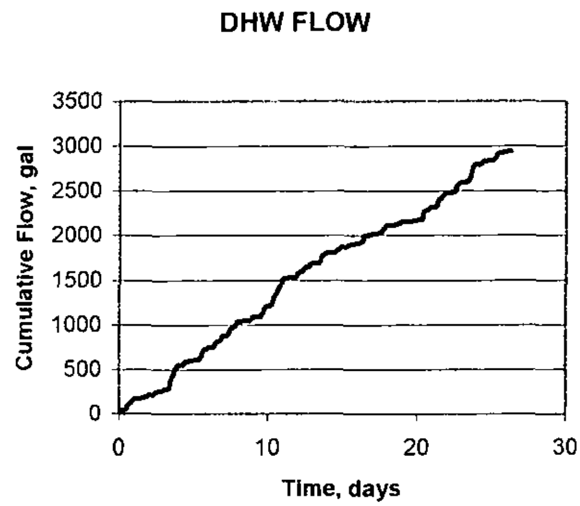


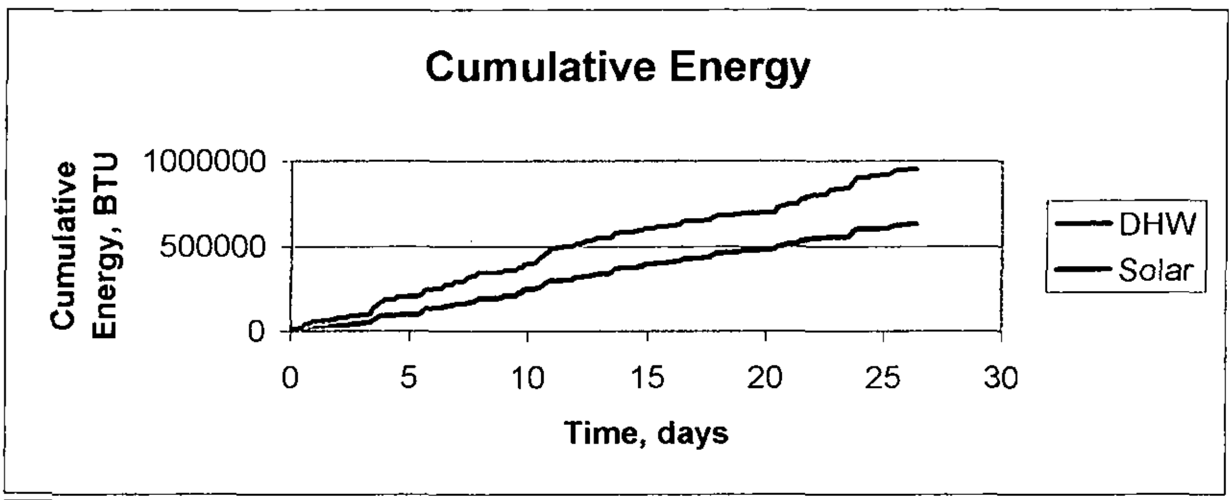


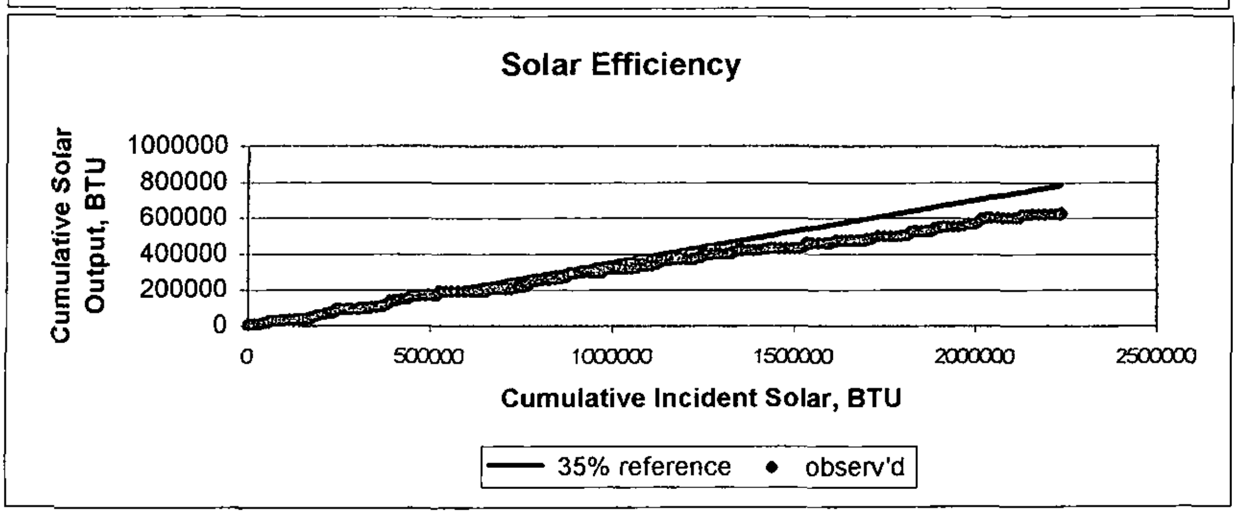


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW2 - pont12a.xls

Start date	end date	
28-Aug-00	23-Sep-00	
Month	Sep	
Duration	26.38	days
Mean Inlet Temp	71.9	deg F
Mean Outlet Temp	110.8	deg F
Mean DHW usage	111.4	gal/day
Mean DHW BTU/day	36,097	BTU/day
Mean Solar BTU/day	23,817	BTU/day
Solar Contribution	66%	
HX Performance	132	BTU/deghr
DHW tank factor	0.86	
Solar tank factor	0.96	
Incident Solar	1,420	BTU/ft2/da
Mean Efficiency	29%	
Electric standby	6,111	BTU/day

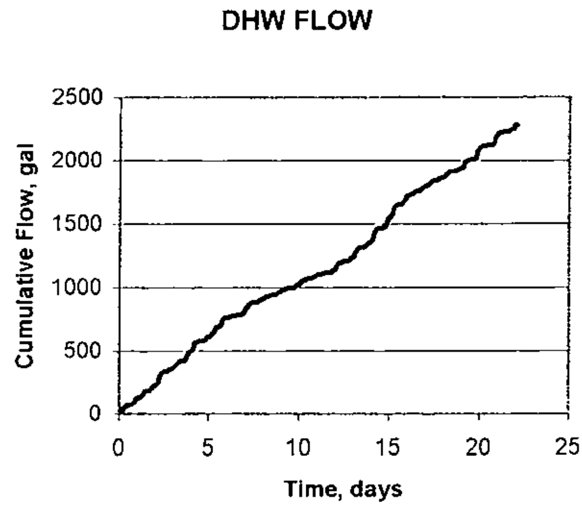


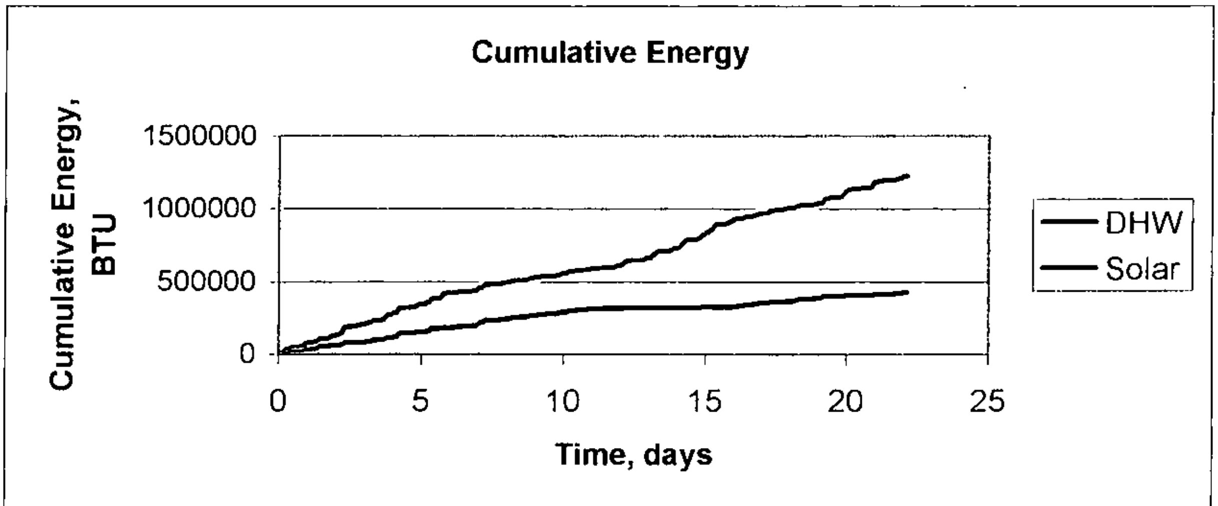


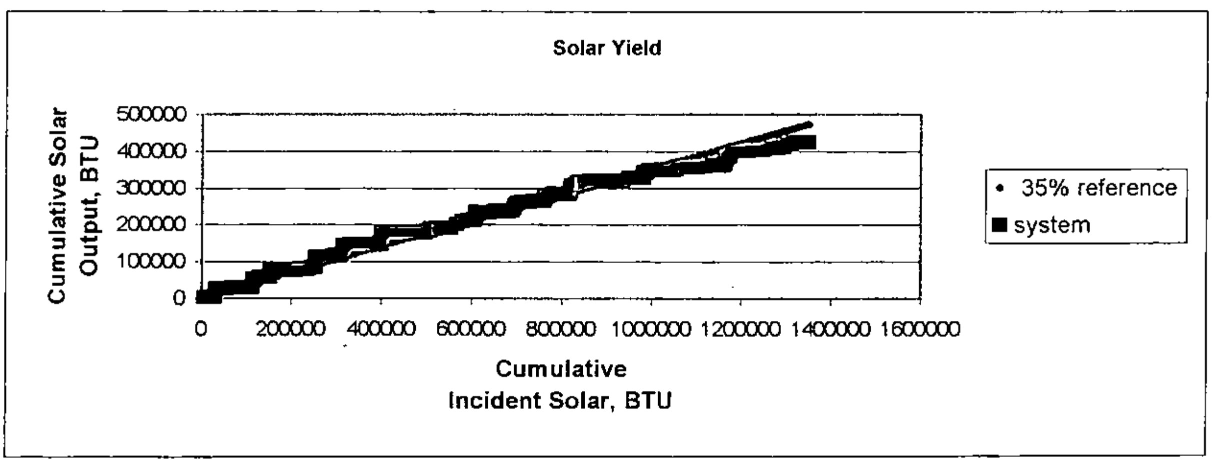


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau3a1

Start date	end date	
5/8	5/30	
Month	May	
Duration	22.17	days
Mean Inlet Temp	63.4	deg F
Mean Outlet Temp	127.9	deg F
Mean DHW usage	102.8	gal/day
Mean DHW BTU/day	55,217	BTU/day
Mean Solar BTU/day	19,066	BTU/day
Solar Contribution	35%	
HX Performance	233	BTU/deghr
DHW tank factor	0.82	
Solar tank factor	0.73	
Incident Solar	1,311	BTU/ft2/day
Mean Efficiency	31%	
Electric standby	8,440	BTU/day

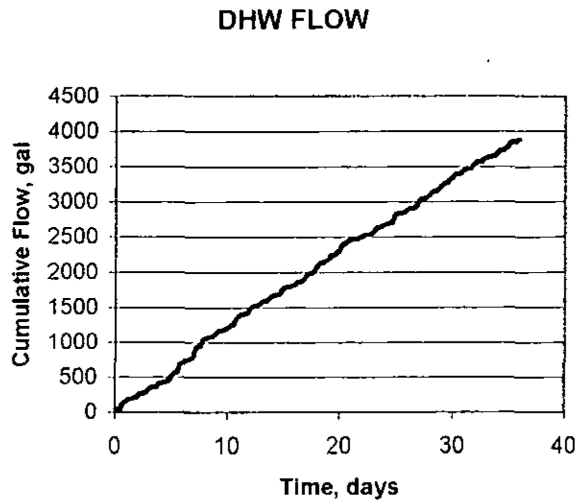


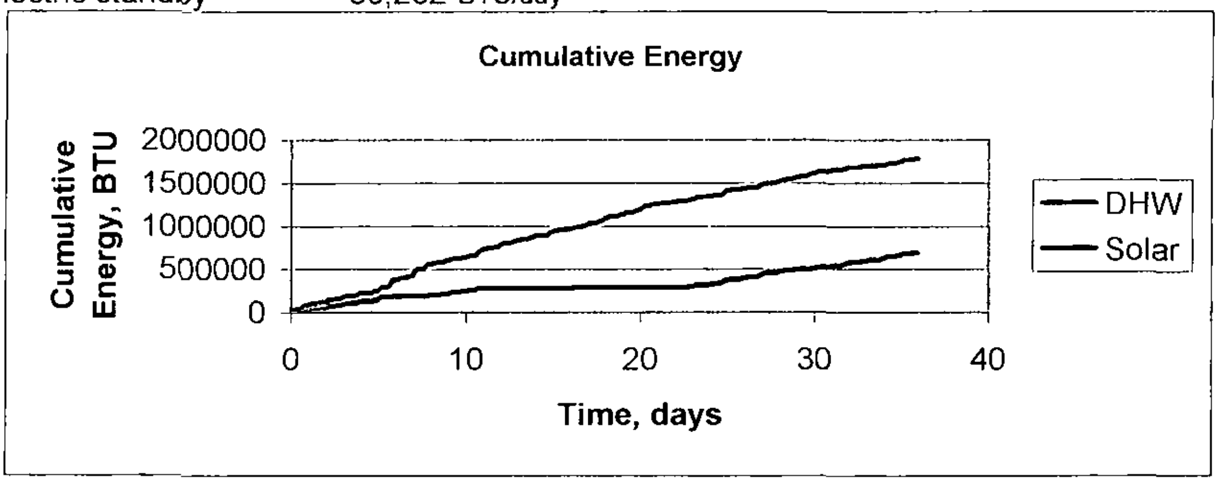


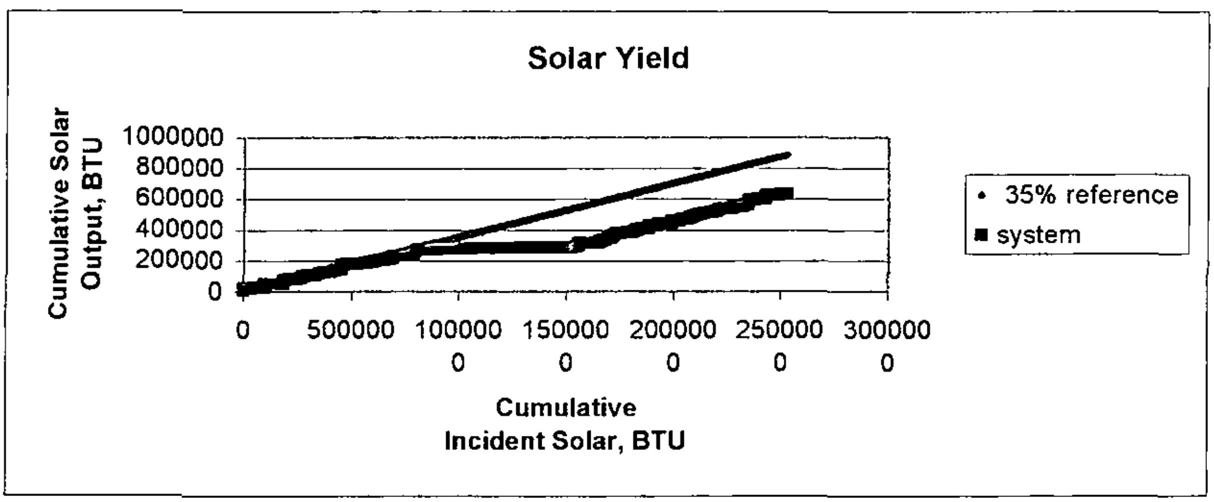


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau4a1

Start date	end date	
5/30	7/5	
Month	*Jun*	
Duration	36.00	days
Mean Inlet Temp	67.5	deg F
Mean Outlet Temp	122.5	deg F
Mean DHW usage	107.9	gal/day
Mean DHW BTU/day	49,406	BTU/day
Mean Solar BTU/day	19,147	BTU/day
Solar Contribution	39%	
HX Performance	166	*BTU/deghr*
DHW tank factor	2.58	
Solar tank factor	0.99	
Incident Solar	1,510	BTU/ft2/day
Mean Efficiency	25%	
Electric standby	-30,232	BTU/day

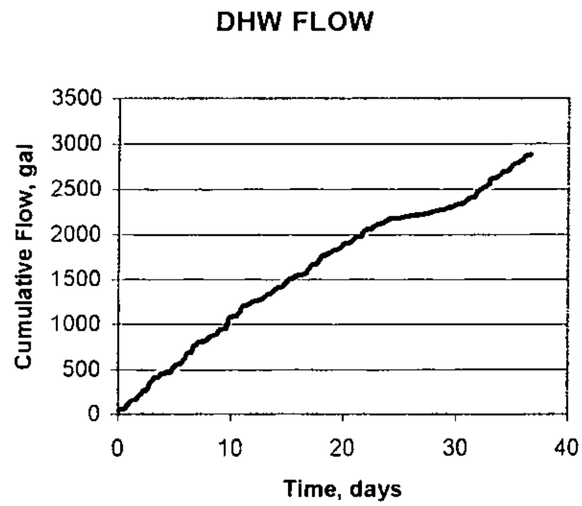


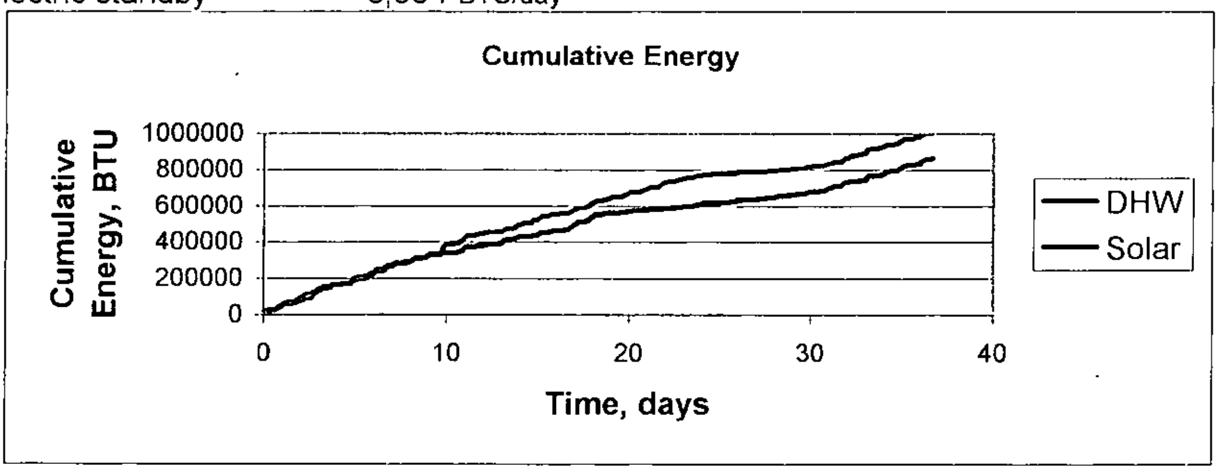


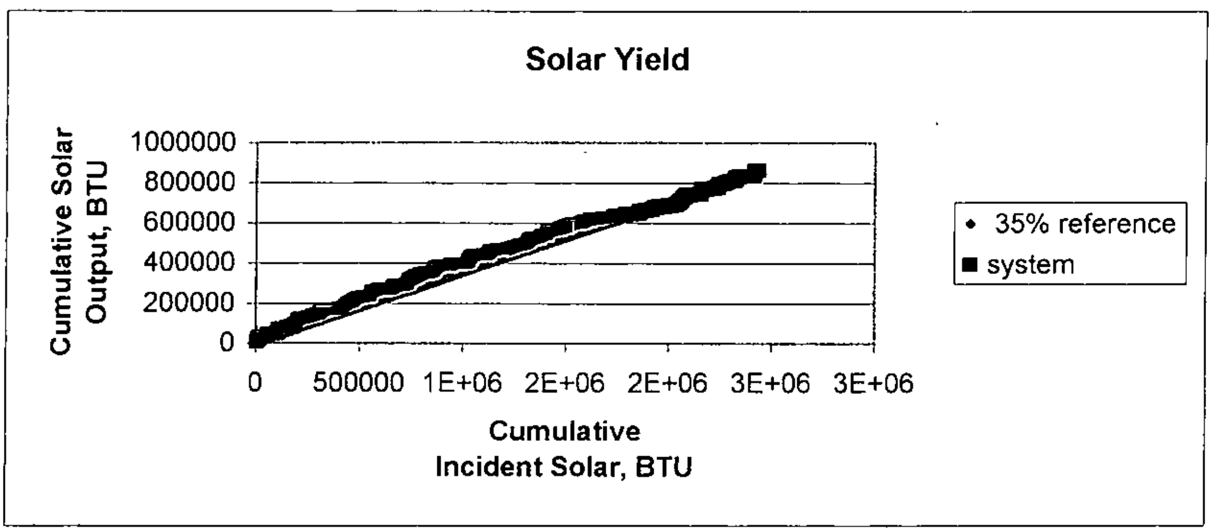


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau5a1

Start date	end date
7/5	8/11
Month	Jul
Duration	36.75 days
Mean Inlet Temp	75.8 deg F
Mean Outlet Temp	117.7 deg F
Mean DHW usage	78.4 gal/day
Mean DHW BTU/day	27,368 BTU/day
Mean Solar BTU/day	23,434 BTU/day
Solar Contribution	86%
HX Performance	169 BTU/deghr
DHW tank factor	1.17
Solar tank factor	1.00
Incident Solar	1,428 BTU/ft2/day
Mean Efficiency	35%
Electric standby	-3,934 BTU/day

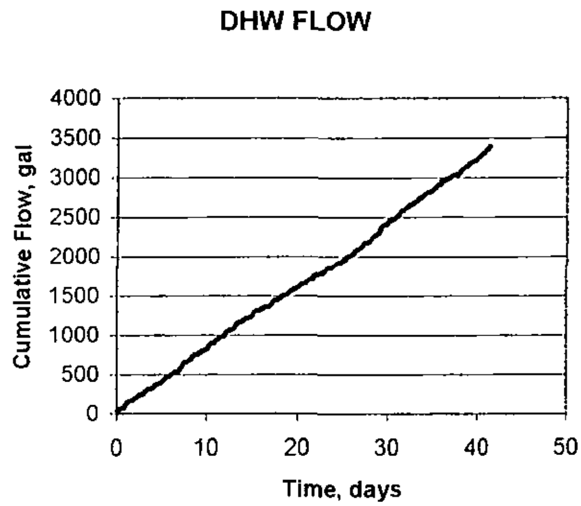


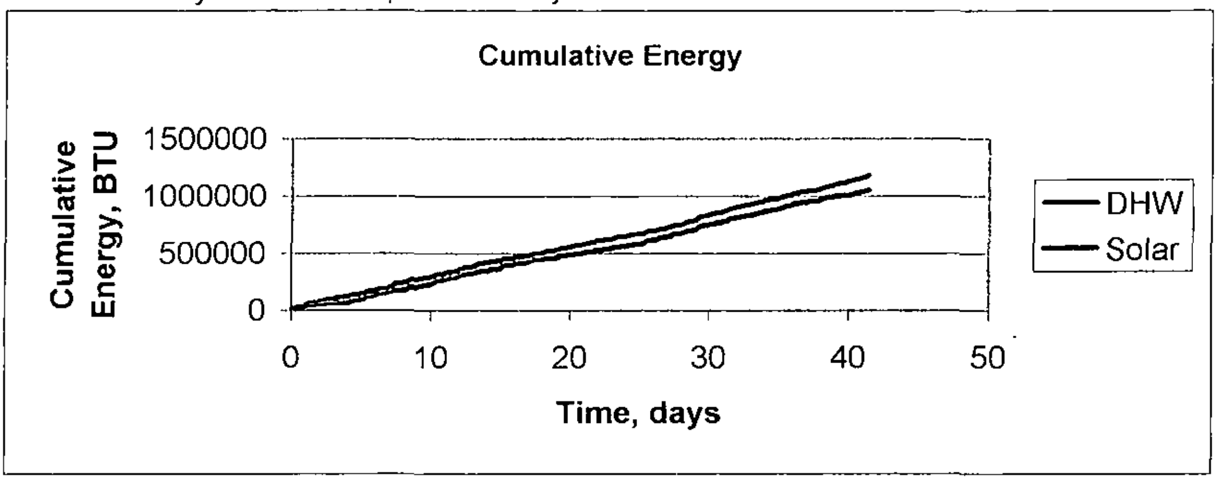


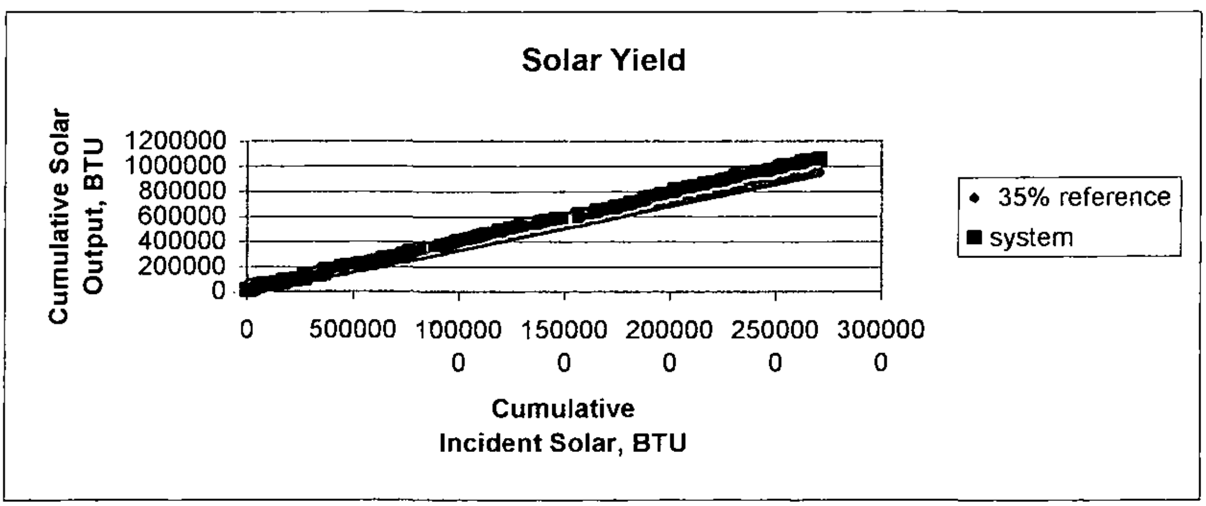


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau6a1

Start date	end date	
8/11	9/21	
Month	Aug	
Duration	41.46	days
Mean Inlet Temp	76.9	deg F
Mean Outlet Temp	118.5	deg F
Mean DHW usage	81.8	gal/day
Mean DHW BTU/day	28,349	BTU/day
Mean Solar BTU/day	25,392	BTU/day
Solar Contribution	90%	
HX Performance	176	BTU/deghr
DHW tank factor	1.12	
Solar tank factor	0.98	
Incident Solar	1,407	BTU/ft2/day
Mean Efficiency	39%	
Electric standby	-2,957	BTU/day

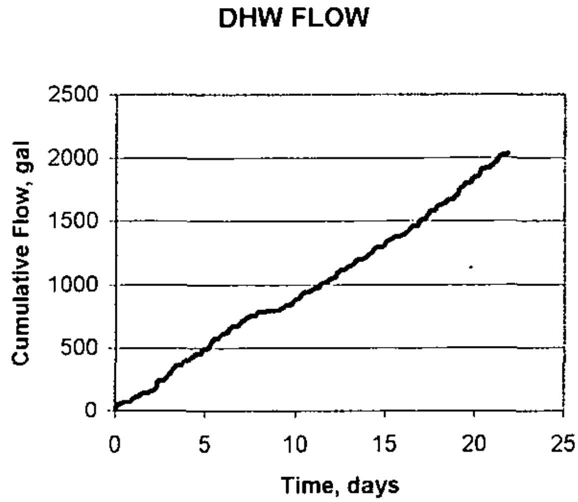


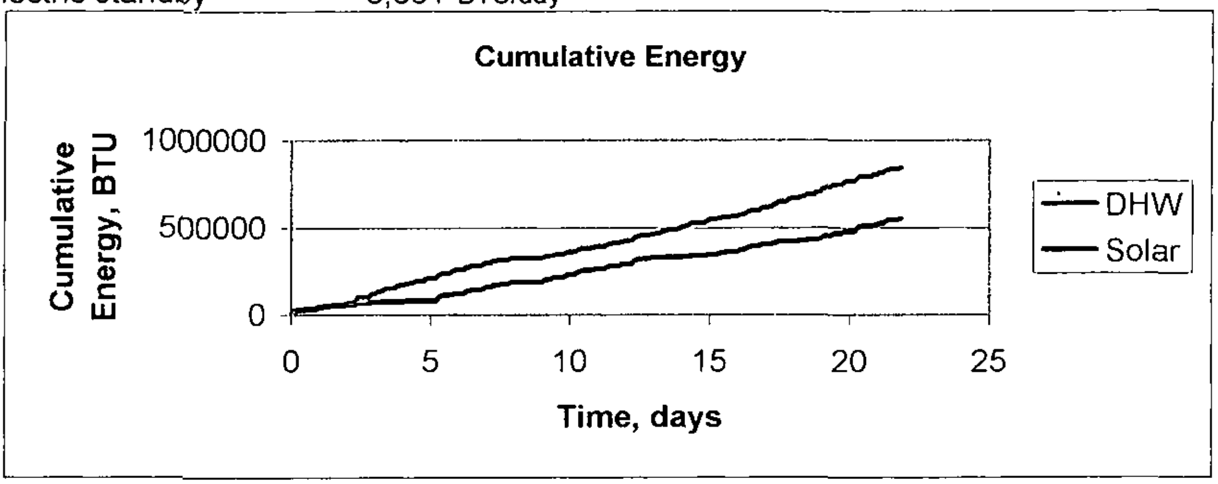


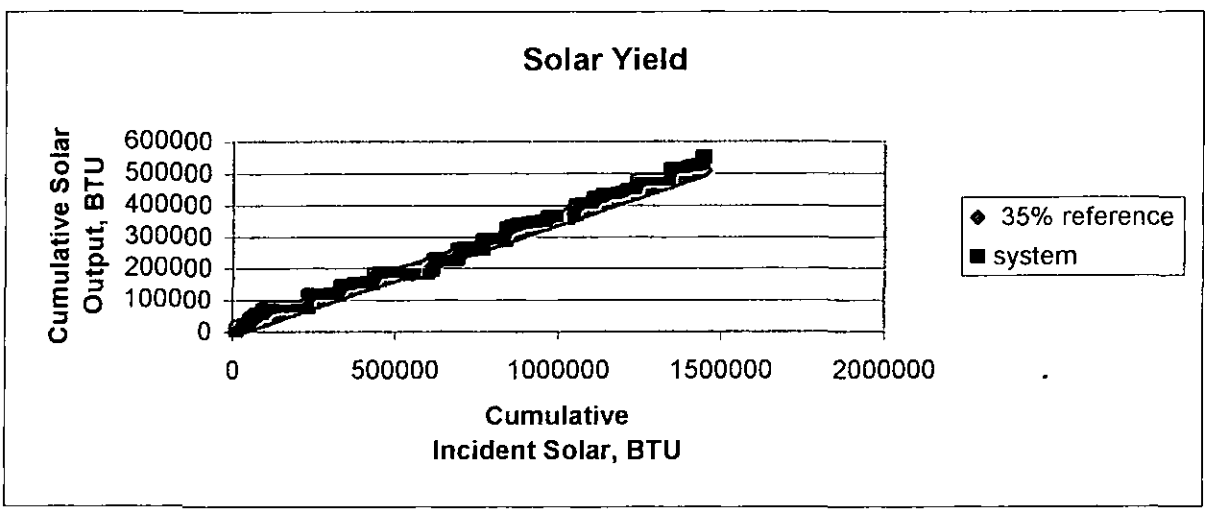


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau7a1

Start date	end date	
9/22	10/14	
Month	Sep	
Duration	21.88	days
Mean Inlet Temp	68.6	deg F
Mean Outlet Temp	118.3	deg F
Mean DHW usage	93.2	gal/day
Mean DHW BTU/day	38,532	BTU/day
Mean Solar BTU/day	25,118	BTU/day
Solar Contribution	65%	
HX Performance	192	BTU/deghr
DHW tank factor	0.78	
Solar tank factor	1.01	
Incident Solar	1,426	BTU/ft2/day
Mean Efficiency	38%	
Electric standby	8,651	BTU/day

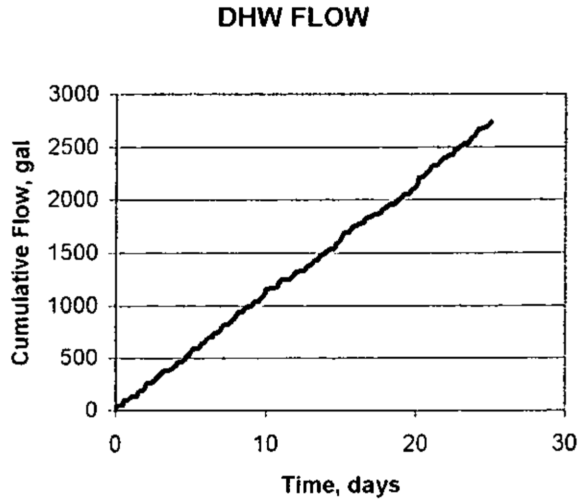


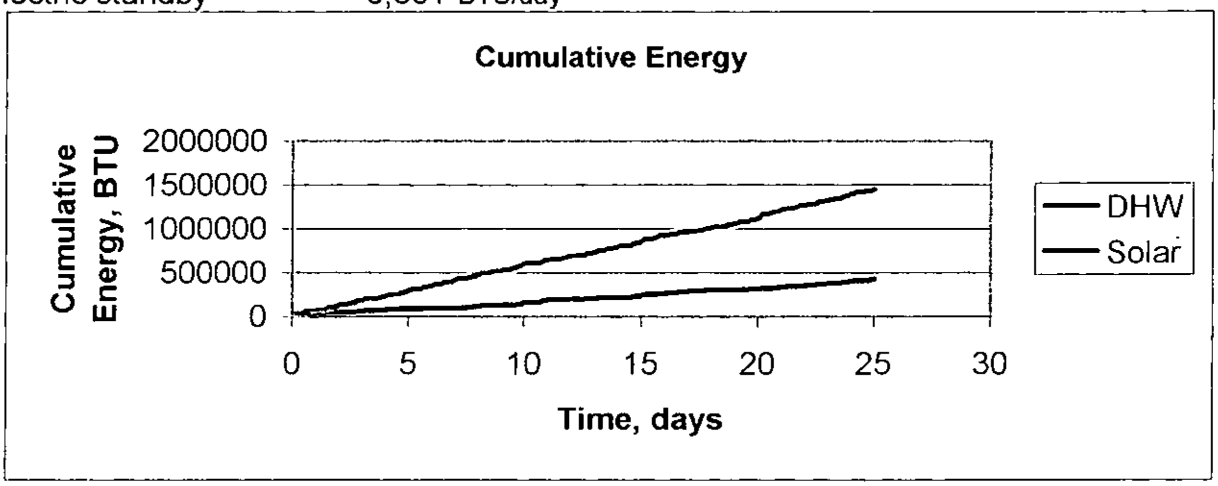


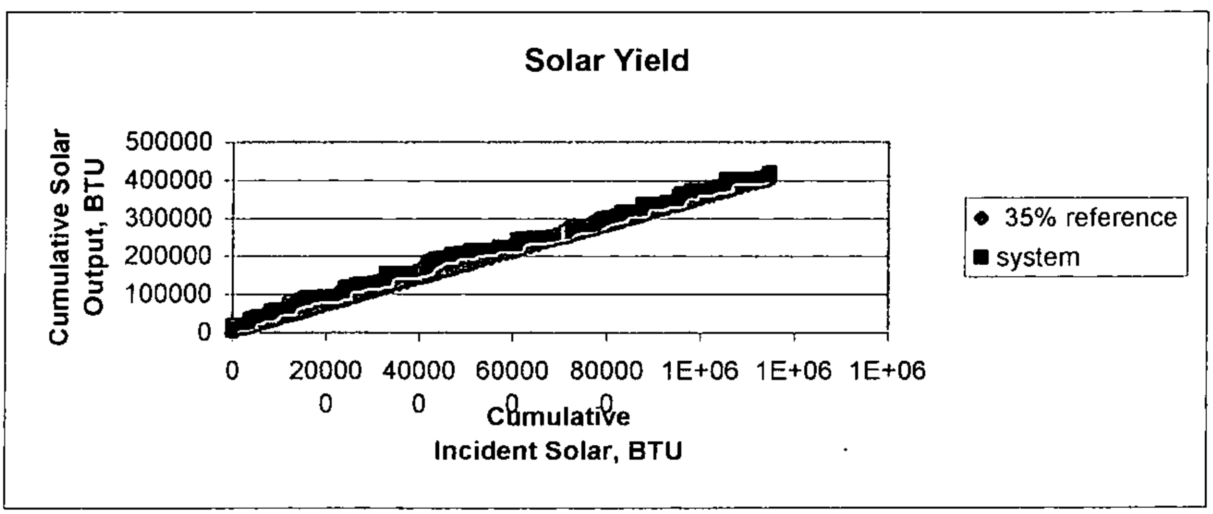


SOLAR DHW SYSTEM MONITORING SUMMARY-DHW3 - strlau8a1

Start date	end date	
11/7	12/2	
Month	Nov	
Duration	25.04	days
Mean Inlet Temp	55.4	deg F
Mean Outlet Temp	118.9	deg F
Mean DHW usage	109.1	gal/day
Mean DHW BTU/day	57,693	BTU/day
Mean Solar BTU/day	16,709	BTU/day
Solar Contribution	29%	
HX Performance	190	BTU/deghr
DHW tank factor	0.86	
Solar tank factor	1.09	
Incident Solar	985	BTU/ft2/day
Mean Efficiency	36%	
Electric standby	9,301	BTU/day

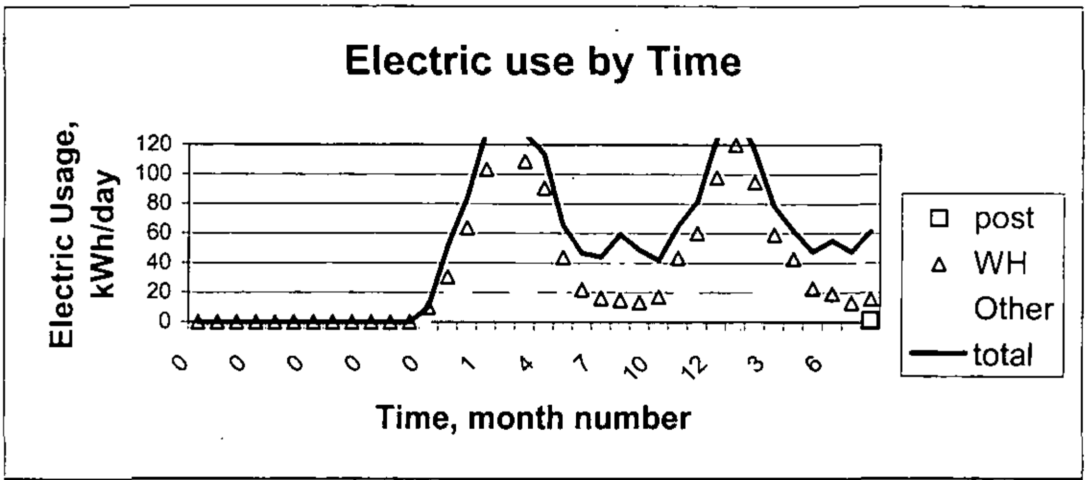


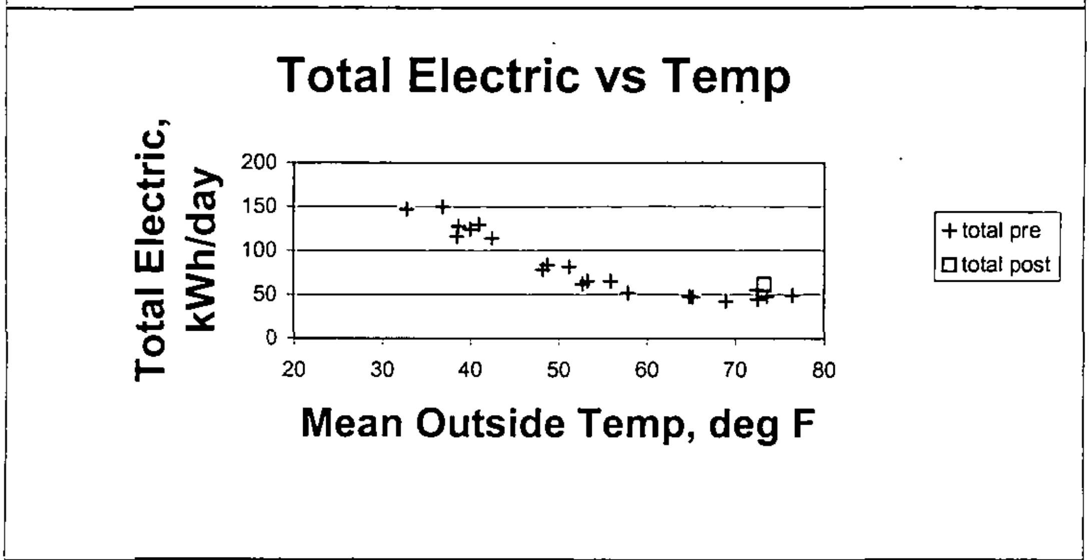


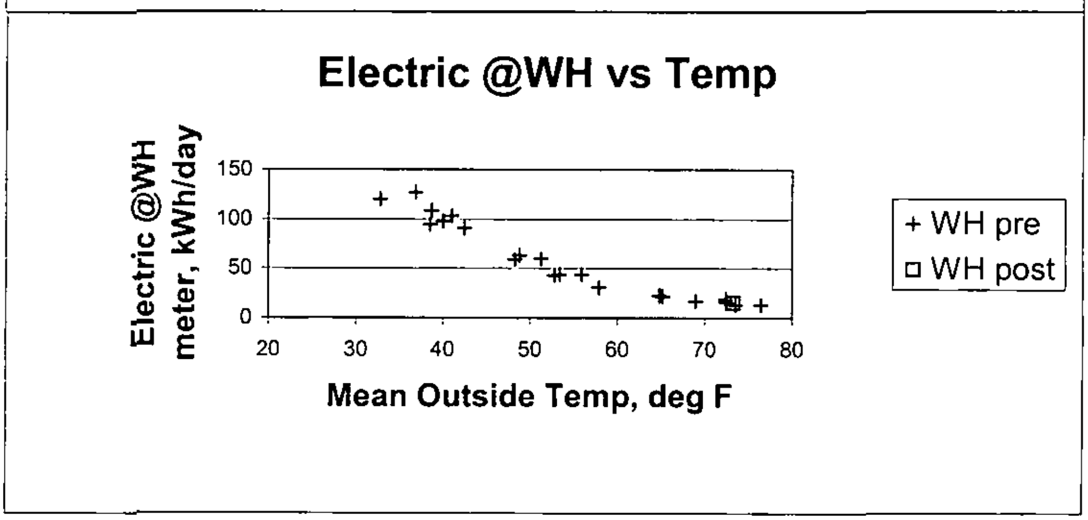


Appendix E. Billing Data Analysis Summaries

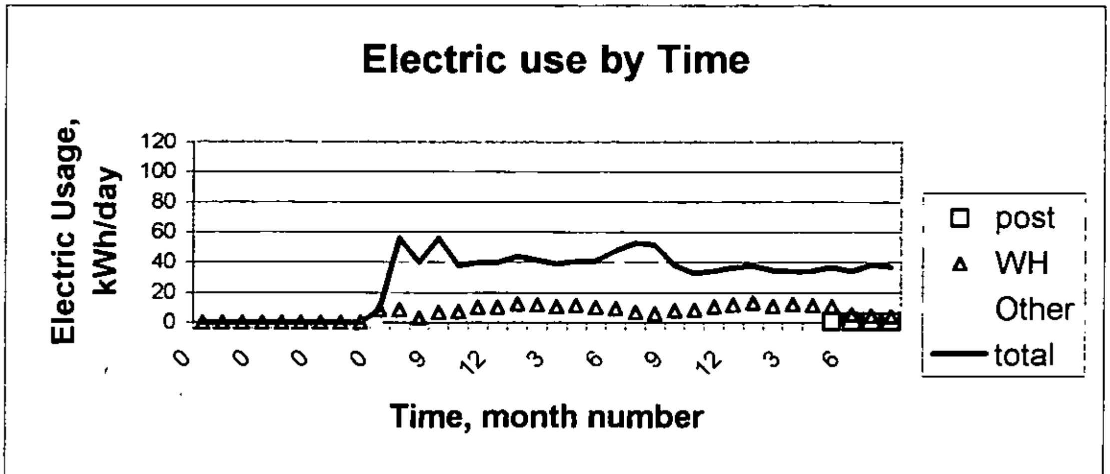
Name	FRED ALFONSI			1 months post	17.28	pre kwh/d
Account	450138017527			24 months total	15.48	post kwh/d
Date retro	08/03/00	latest bill	08/30/00	24 months WH	1.80	sav kwh/d

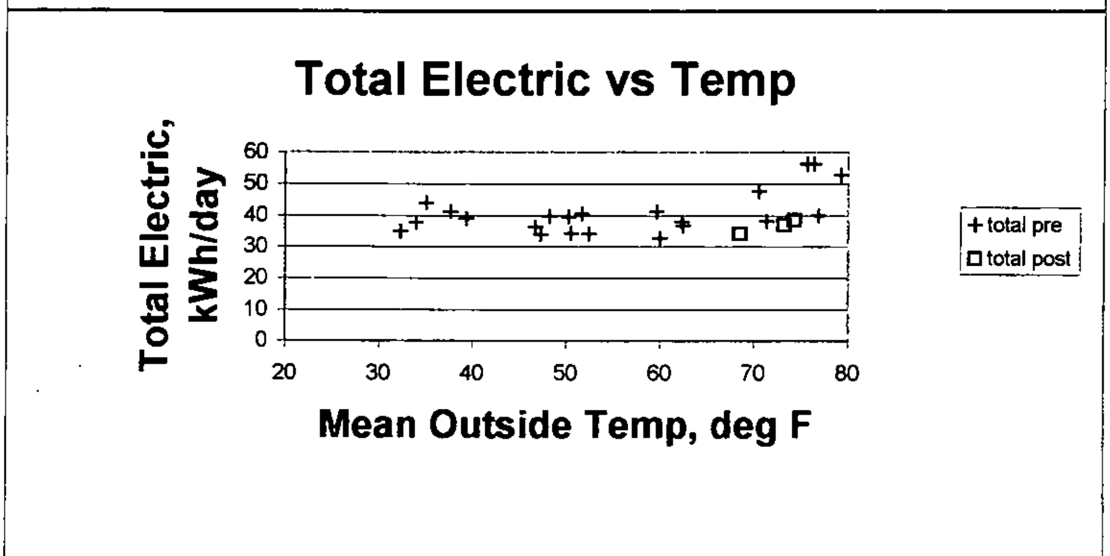


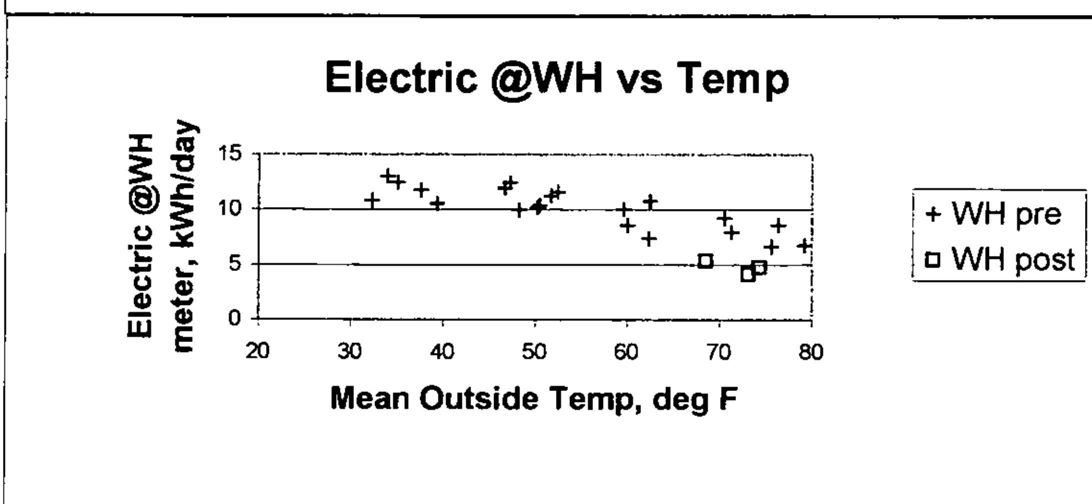




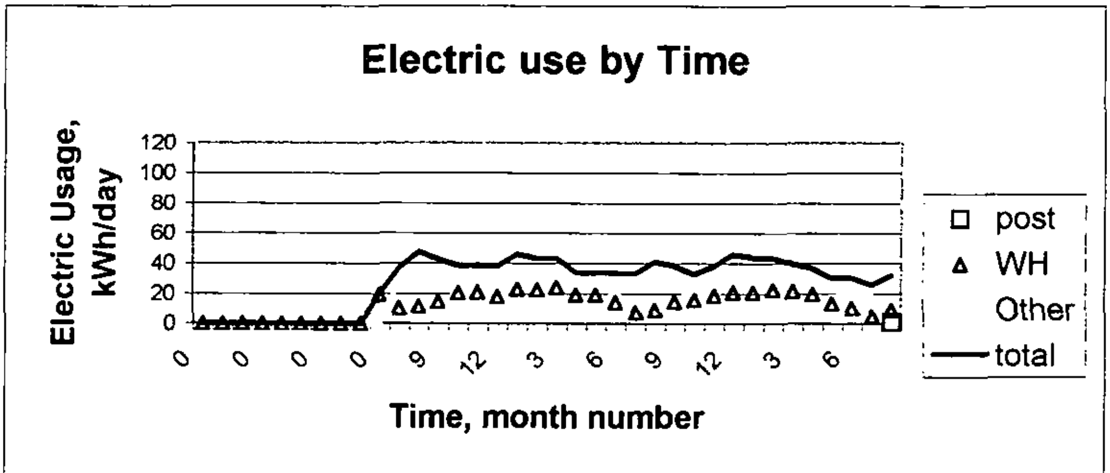
Name	CHRISTINE M VANCE		4 months post	7.48	pre kwh/d
Account	401502220049		27 months total	4.73	post kwh/d
Date retro	05/04/00 latest bill	08/23/00	27 months WH	2.75	sav kwh/d

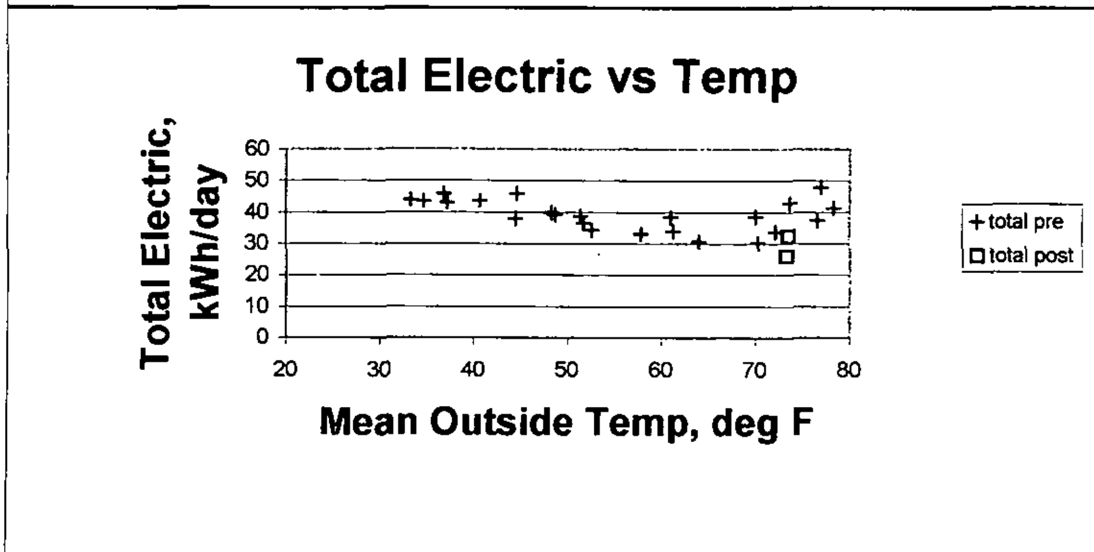


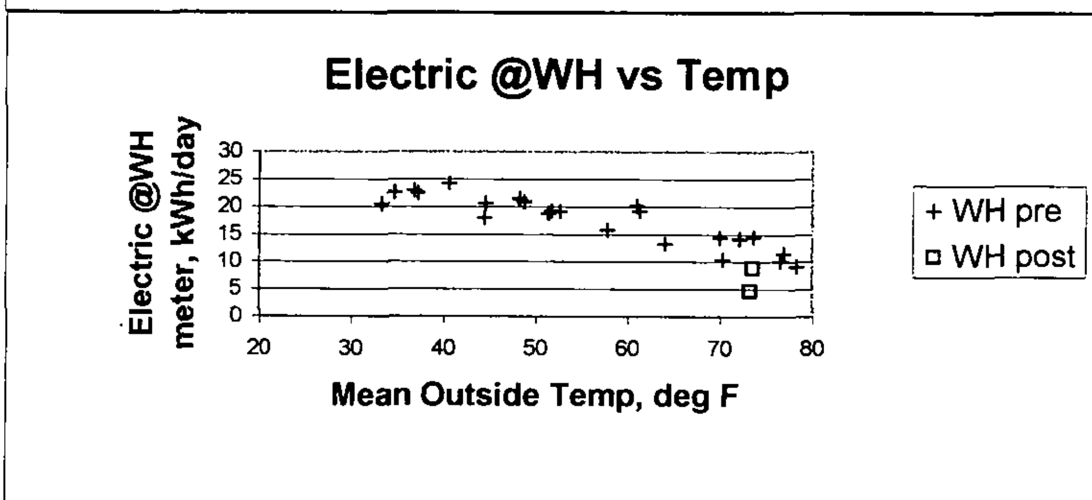




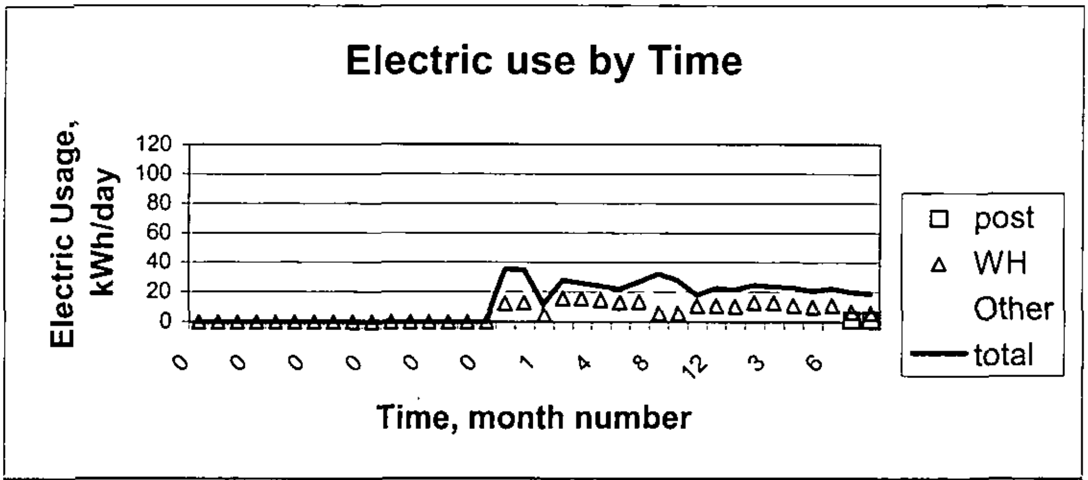
Name	PATRICIA LEWIS		1 months post	13.07 pre kwh/d
Account	351840833054		27 months total	6.72 post kwh/d
Date retro	07/27/00 latest bill	08/28/00	27 months WH	6.35 sav kwh/d

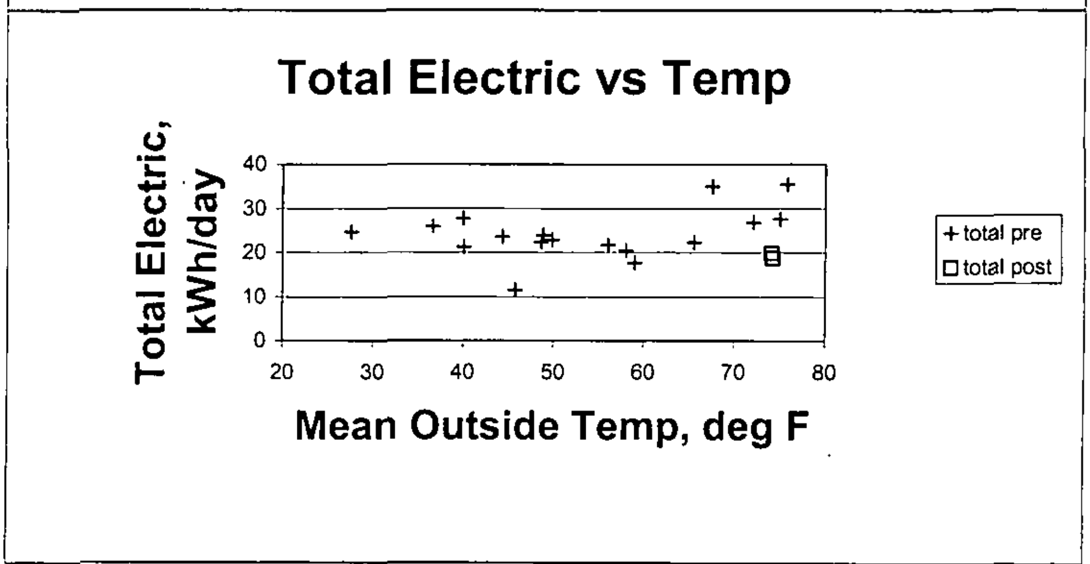


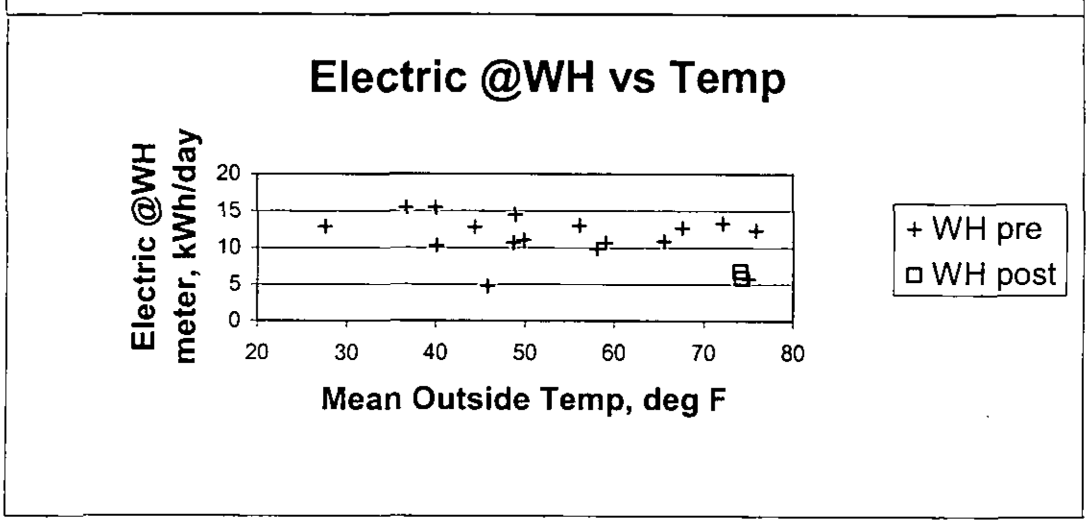




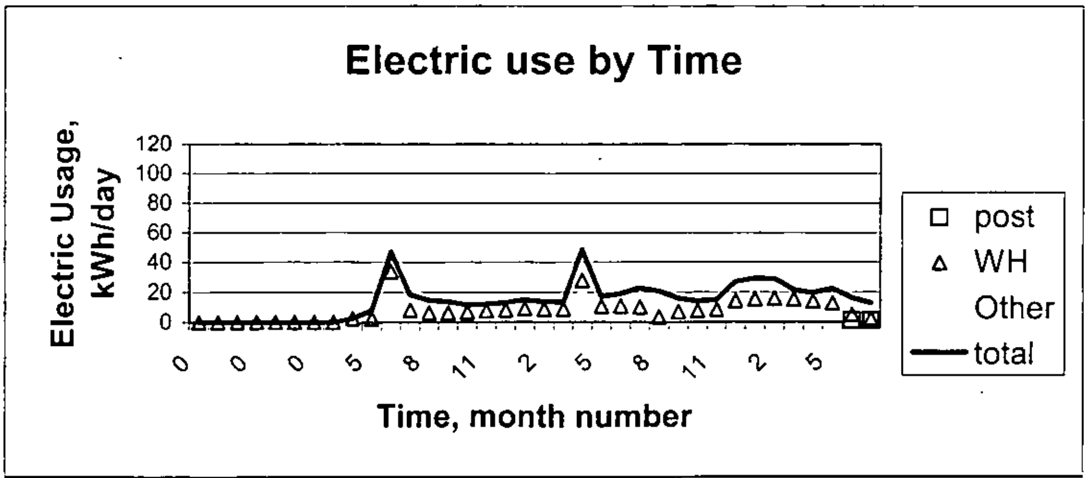
Name DOYLE TUCKER | 2 months post | 10.14 pre kwh/d
Account 500826347048 | 20 months total | 6.32 post kwh/d
Date retro 06/21/00 latest bill 08/11/00 | 20 months WH | 3.82 sav kwh/d

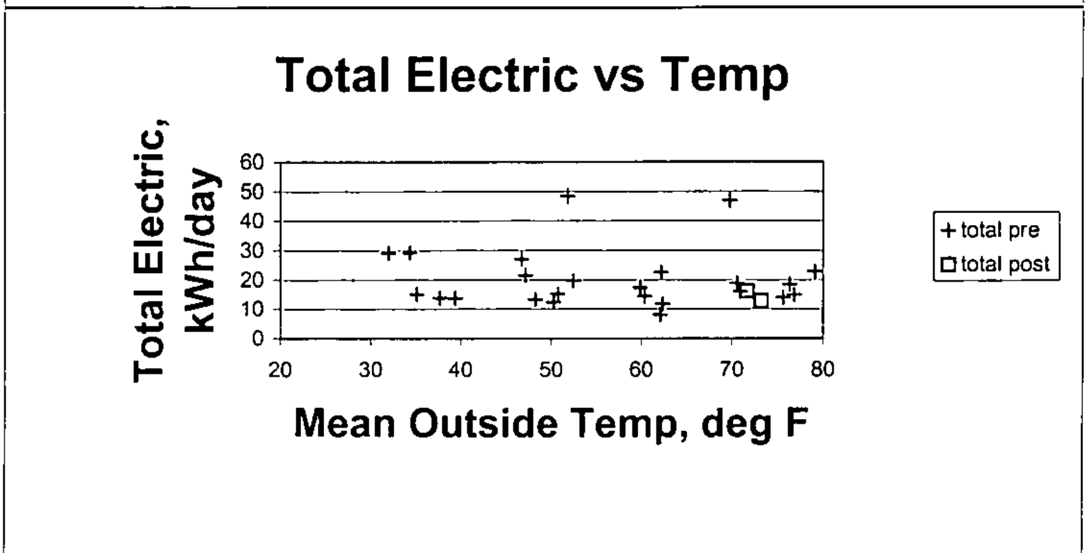


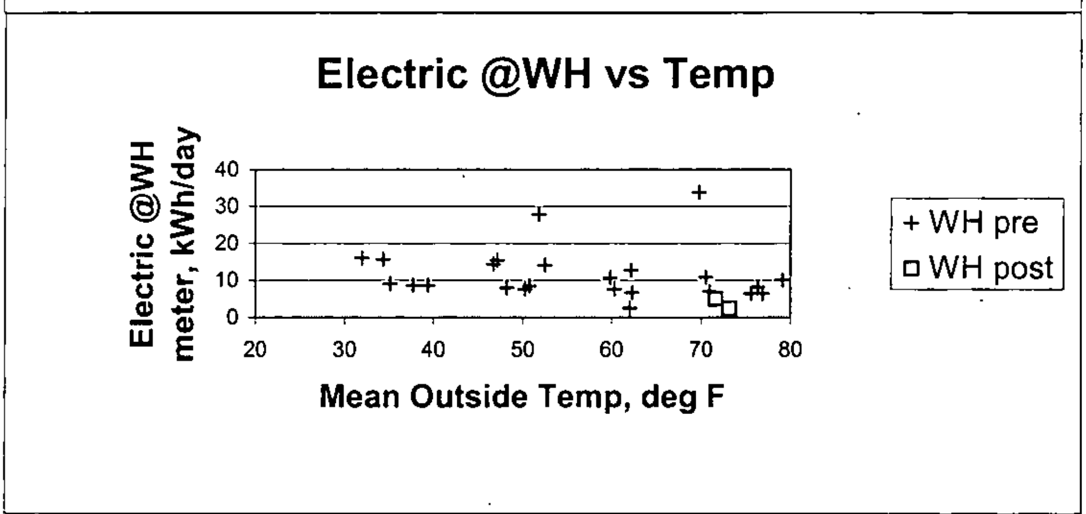




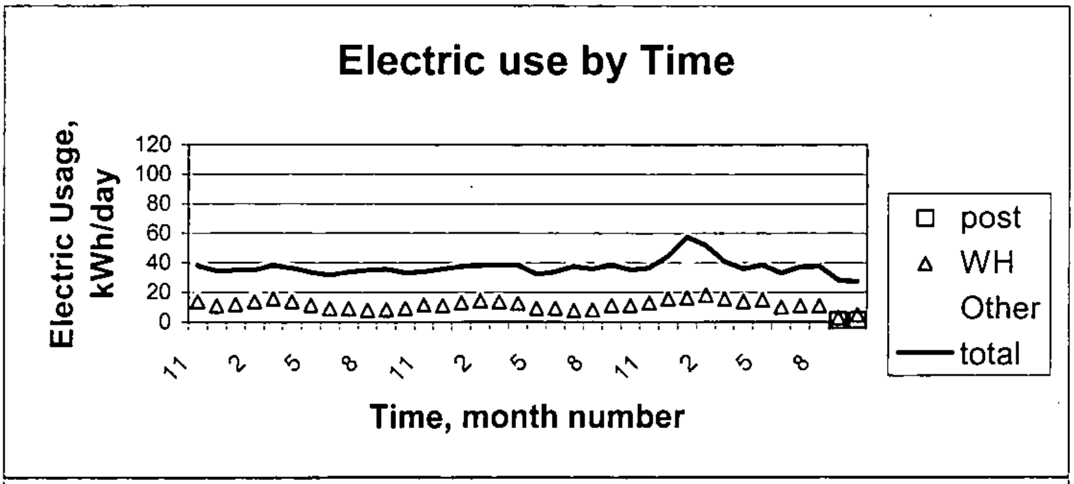
Name	SUSAN A BENDER			2 months post	9.63	pre kwh/d
Account	351542361024			28 months total	3.70	post kwh/d
Date retro	06/23/00	latest bill	08/23/00	28 months WH	5.93	sav kwh/d

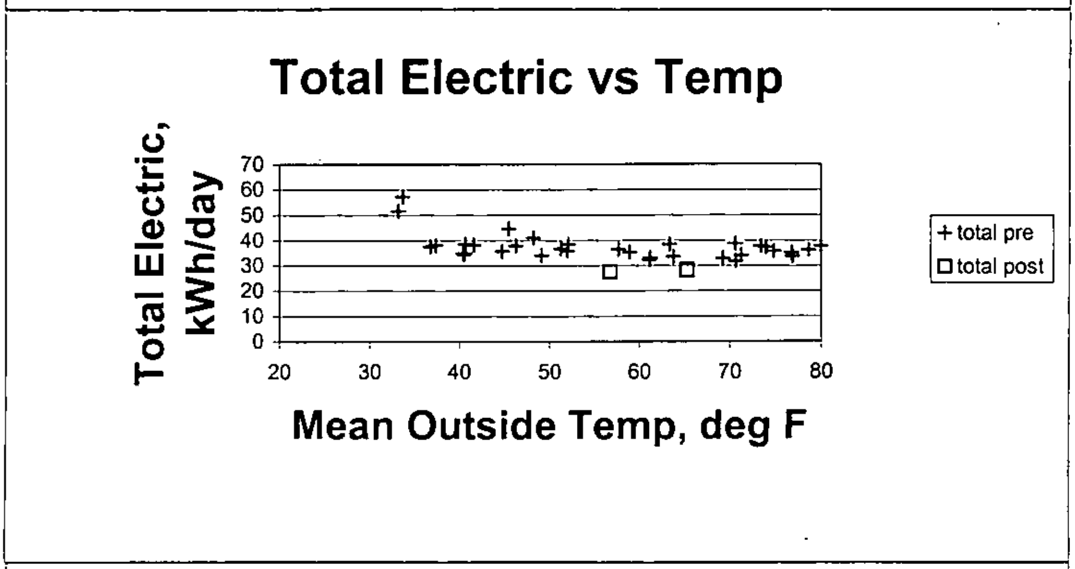


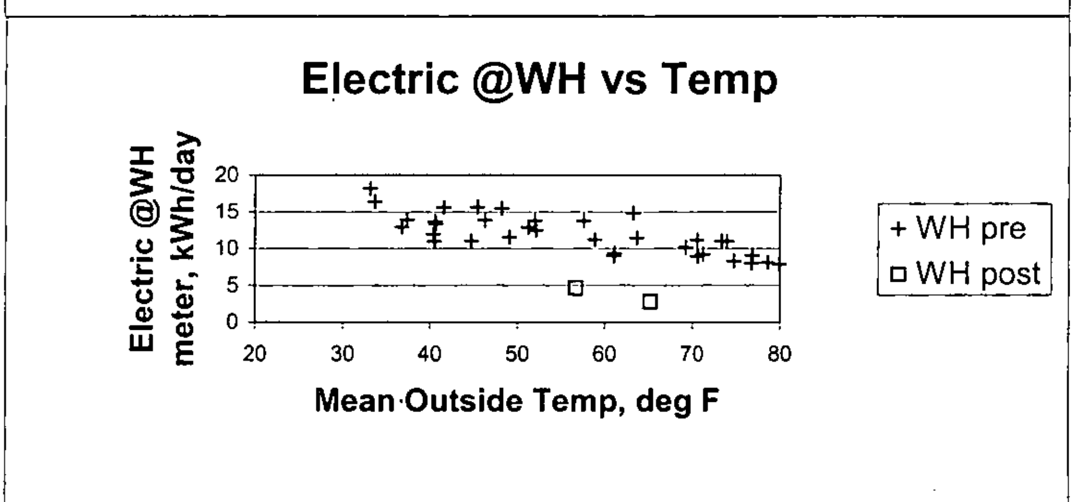




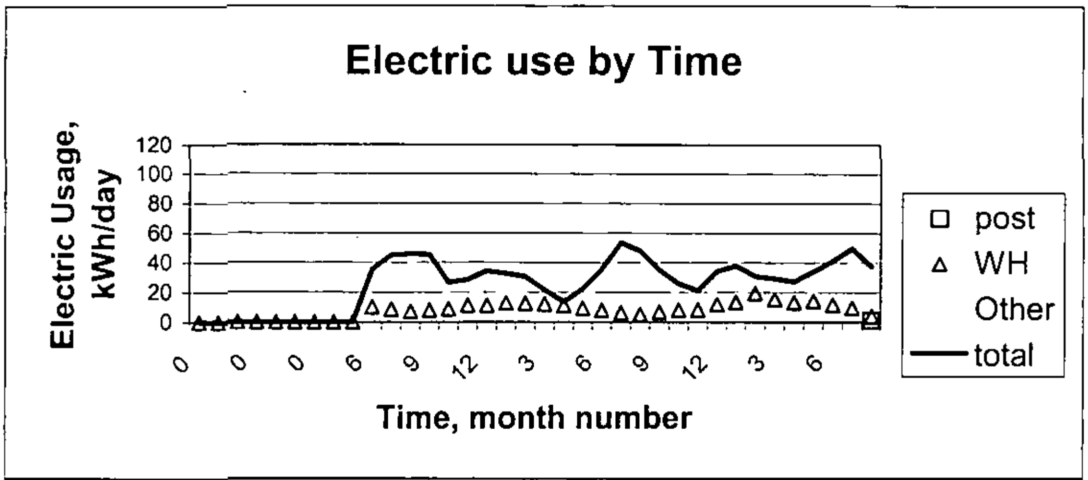
Name	LINDA GREEN		2 months post	9.84	pre kwh/d
Account	261737277622		36 months total	2.81	post kwh/d
Date retro	09/07/00 latest bill	10/25/00	36 months WH	7.03	sav kwh/d

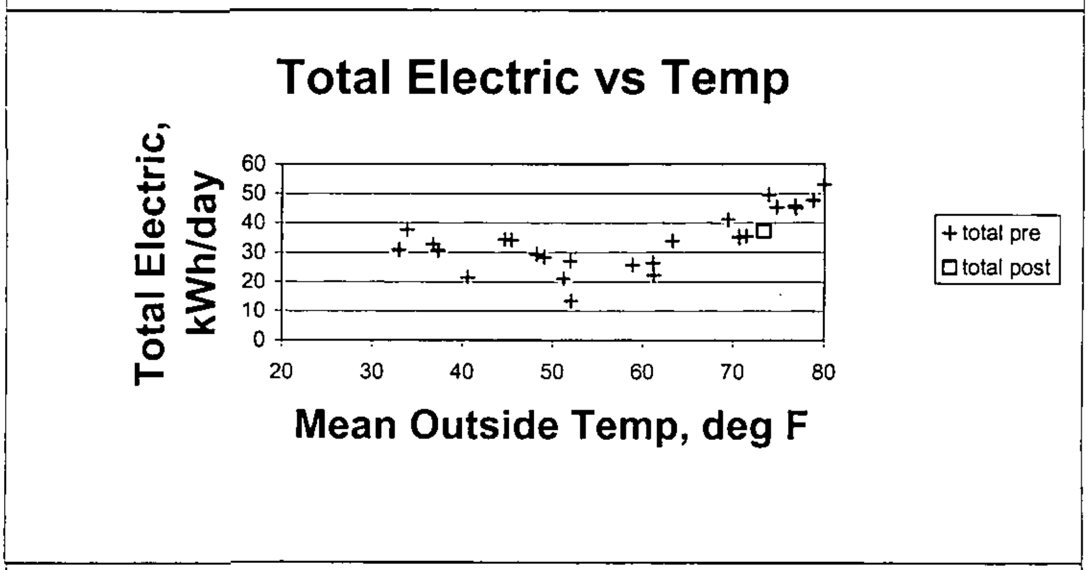


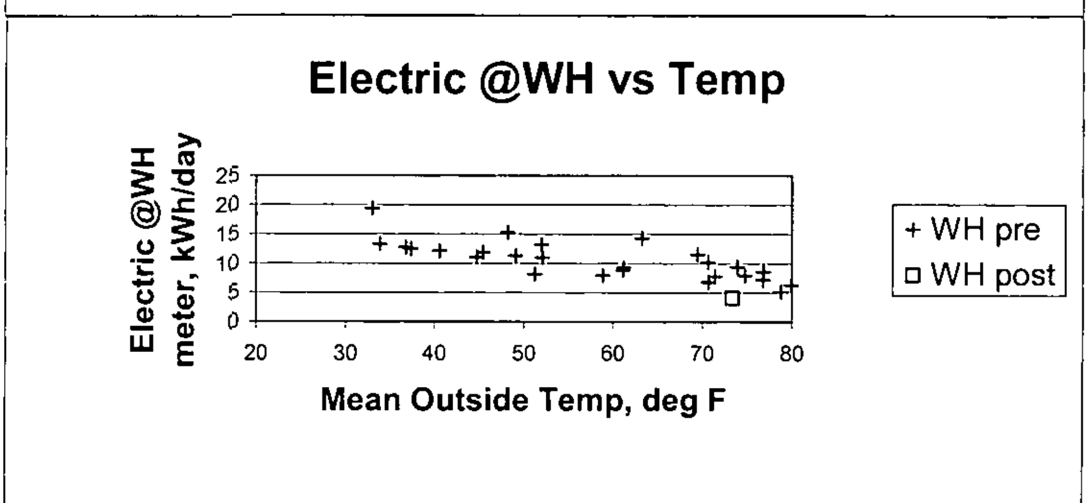




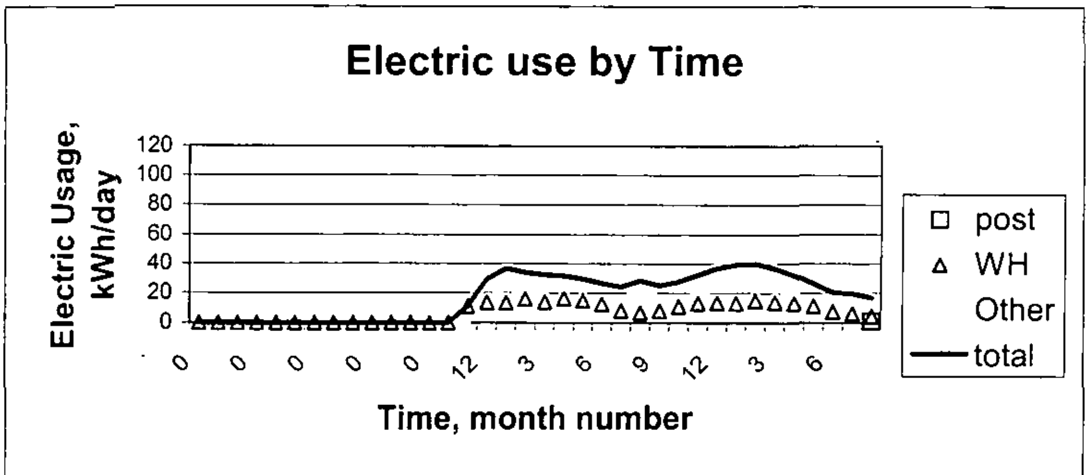
Name	CHRISTINE HUDECHECK JR		1 months post	8.71	pre kwh/d
Account	501721312038		27 months total	4.06	post kwh/d
Date retro	08/17/00 latest bill	08/25/00	27 months WH	4.64	sav kwh/d

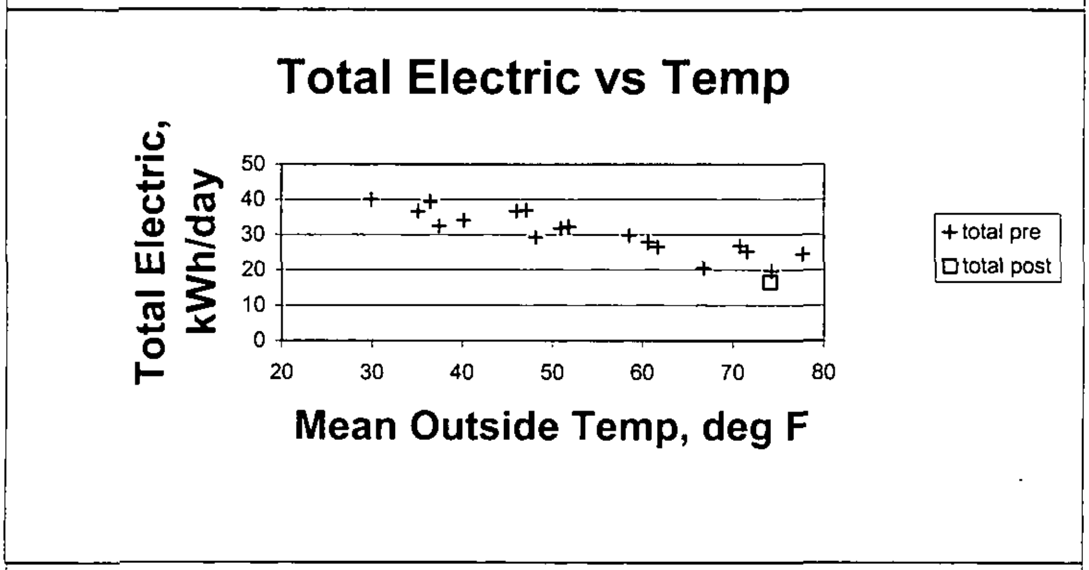


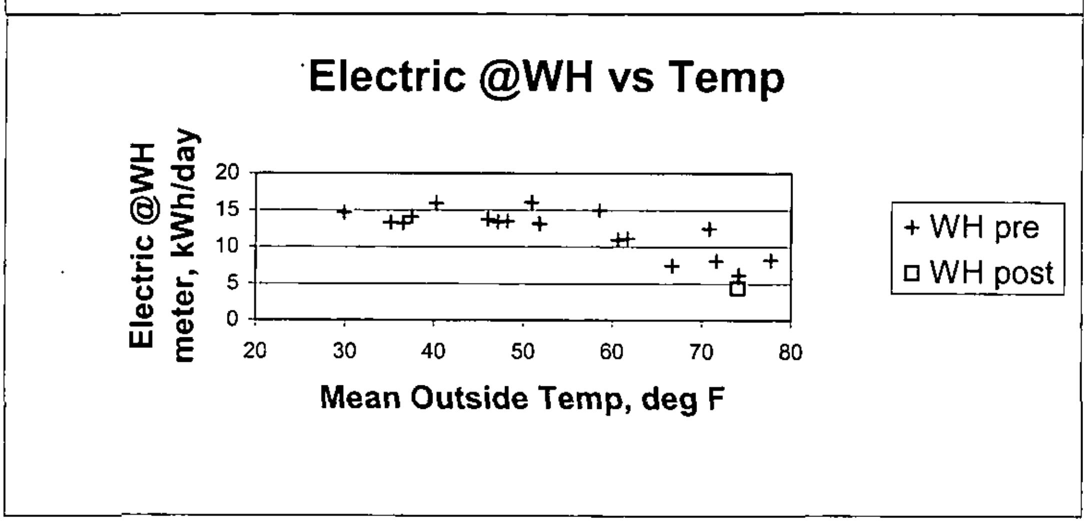




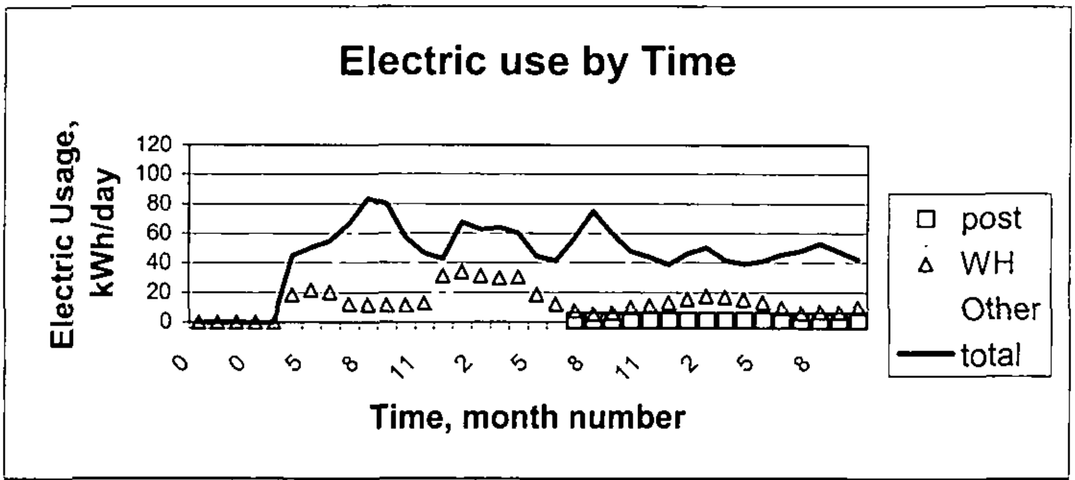
Name	VIRGINIA MACK		1 months post	8.87 pre kwh/d
Account	351343685555		22 months total	4.38 post kwh/d
Date retro	08/10/00 latest bill	08/18/00	22 months WH	4.49 sav kwh/d

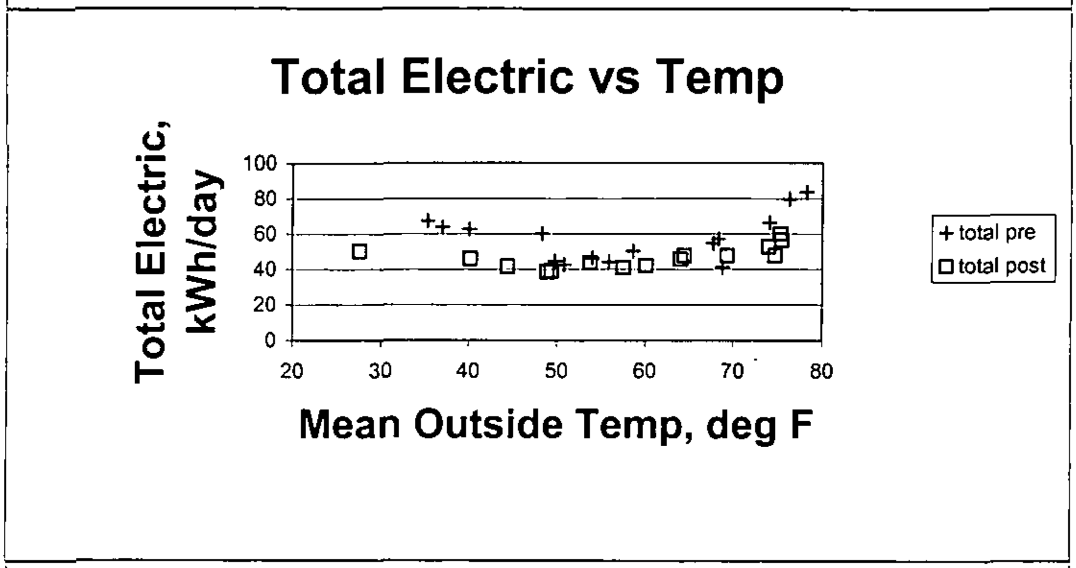


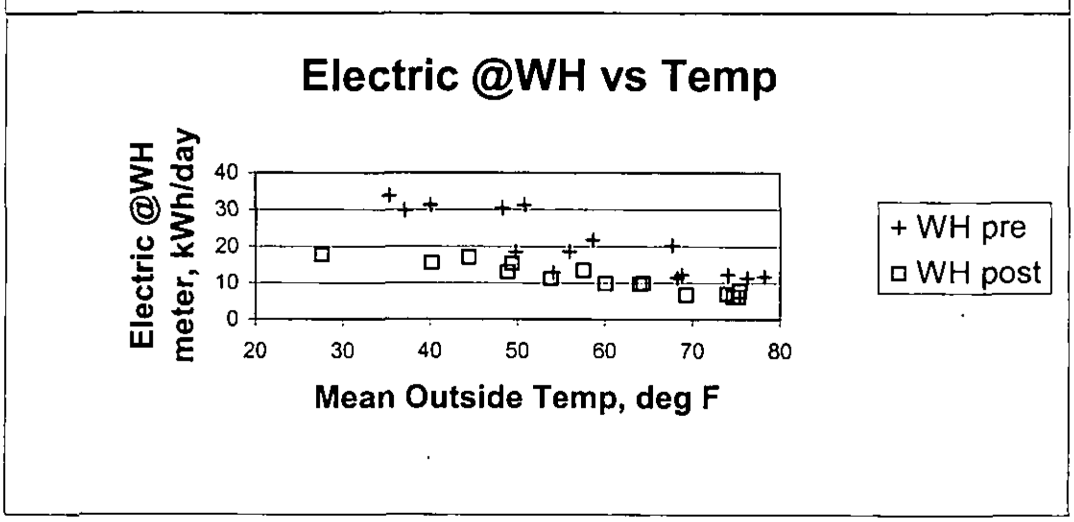




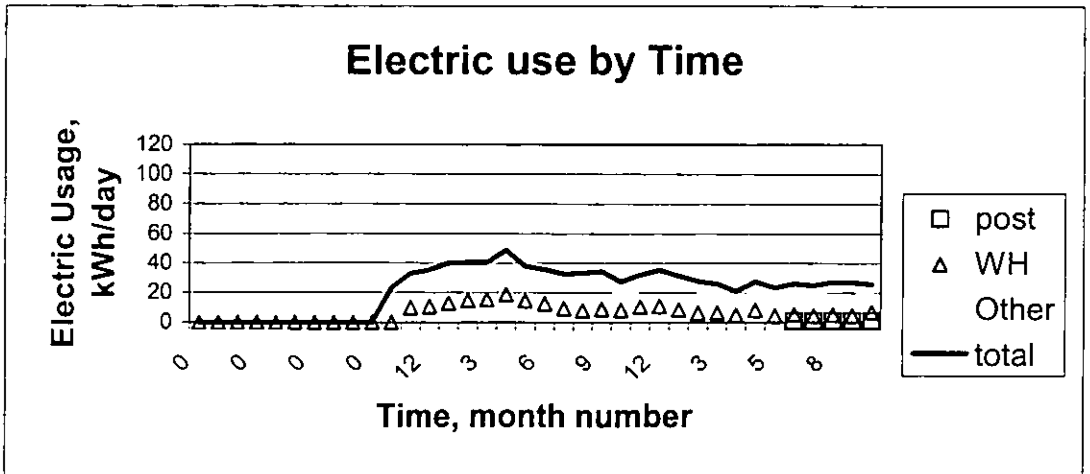
Name	WILLIAM PURNELL		16 months post	13.21	pre kwh/d
Account	260718344815		31 months total	7.63	post kwh/d
Date retro	07/03/99 latest bill	10/10/00	31 months WH	5.59	sav kwh/d

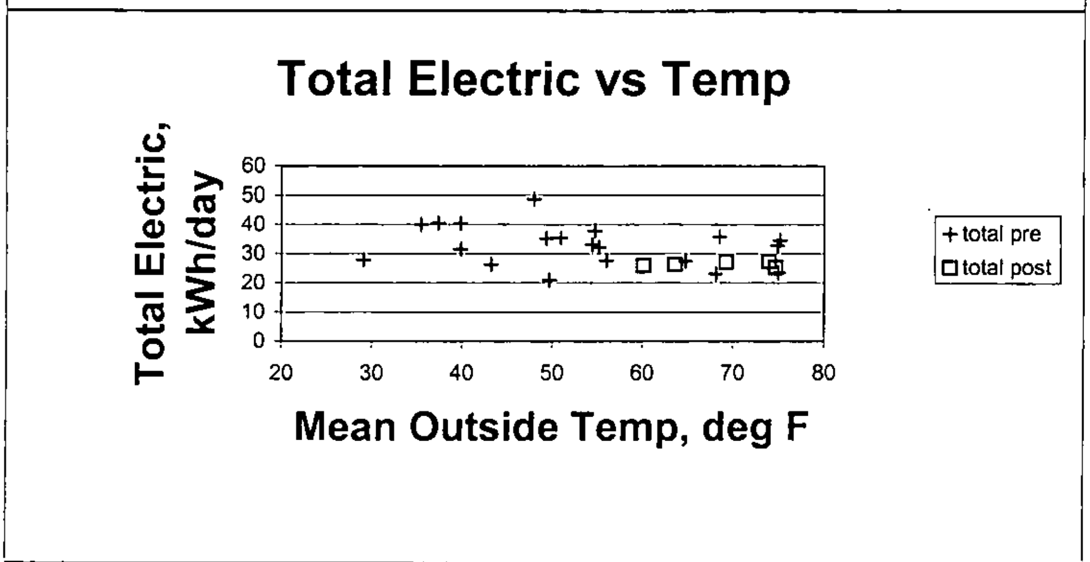


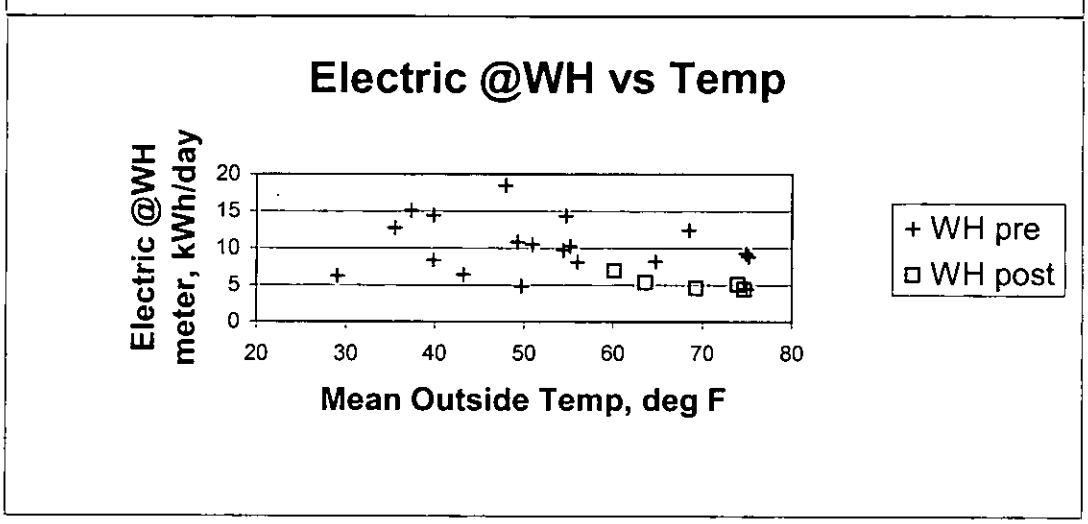




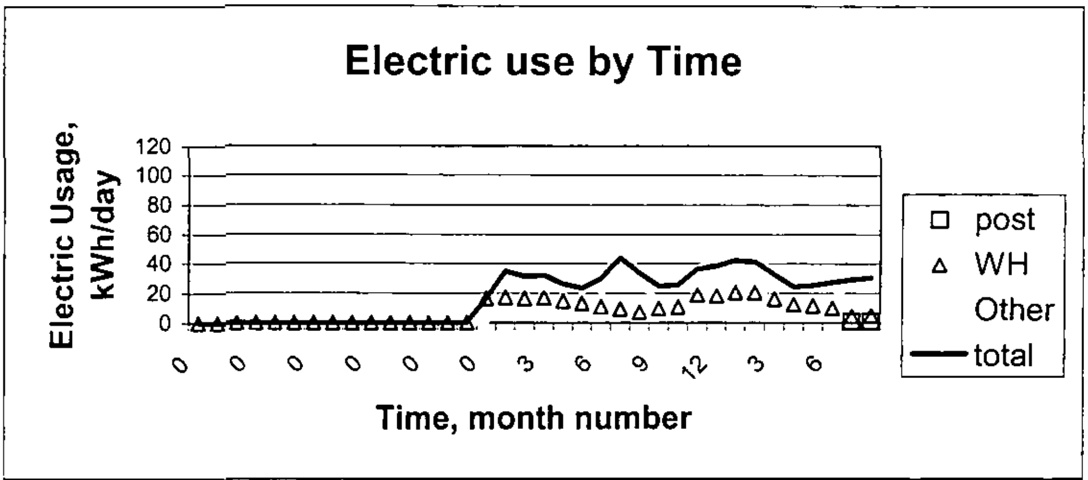
Name FREDERICK H SHULER 5 months post 8.50 pre kwh/d
Account 350641691521 26 months total 5.29 post kwh/d
Date retro 06/02/00 latest bill 10/09/00 25 months WH 3.21 sav kwh/d

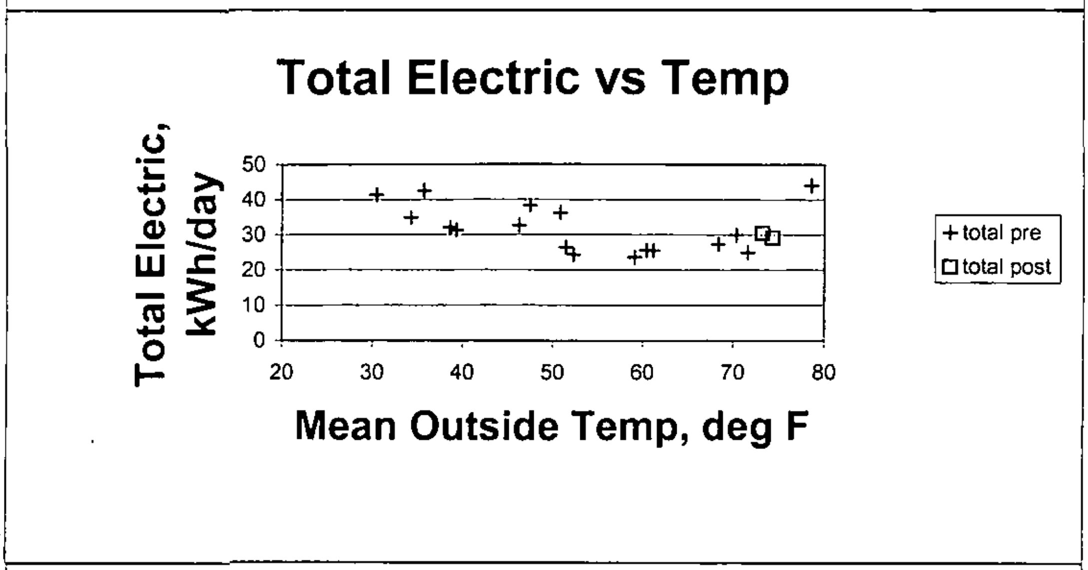


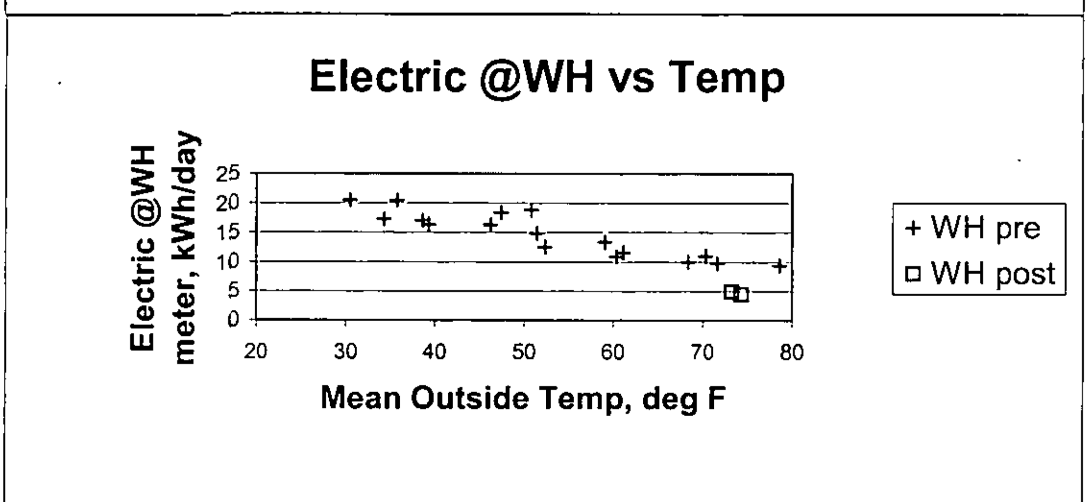




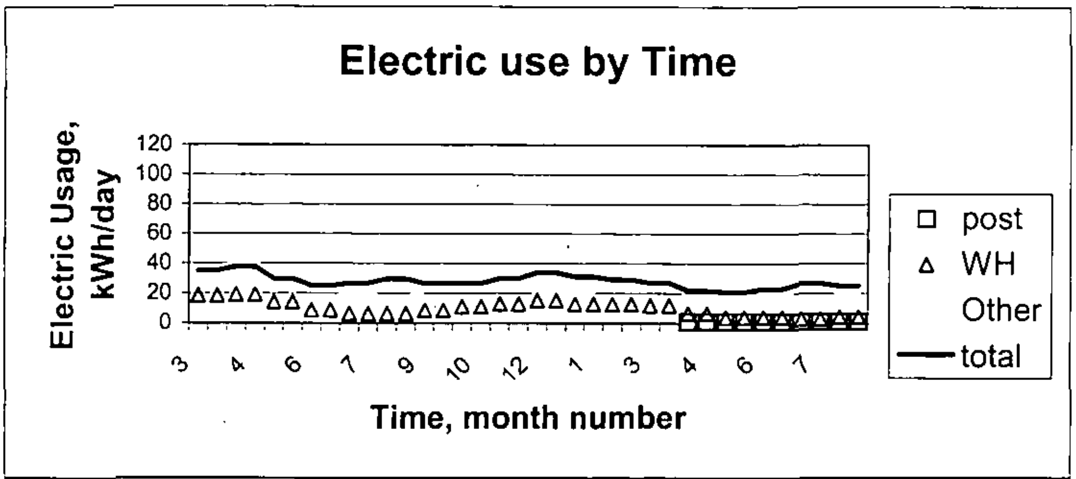
Name	ALAN T SCHULTZ		2	months post	10.02 pre kwh/d
Account	401407697044		21	months total	4.73 post kwh/d
Date retro	07/03/00 latest bill	08/22/00	21	months WH	5.29 sav kwh/d

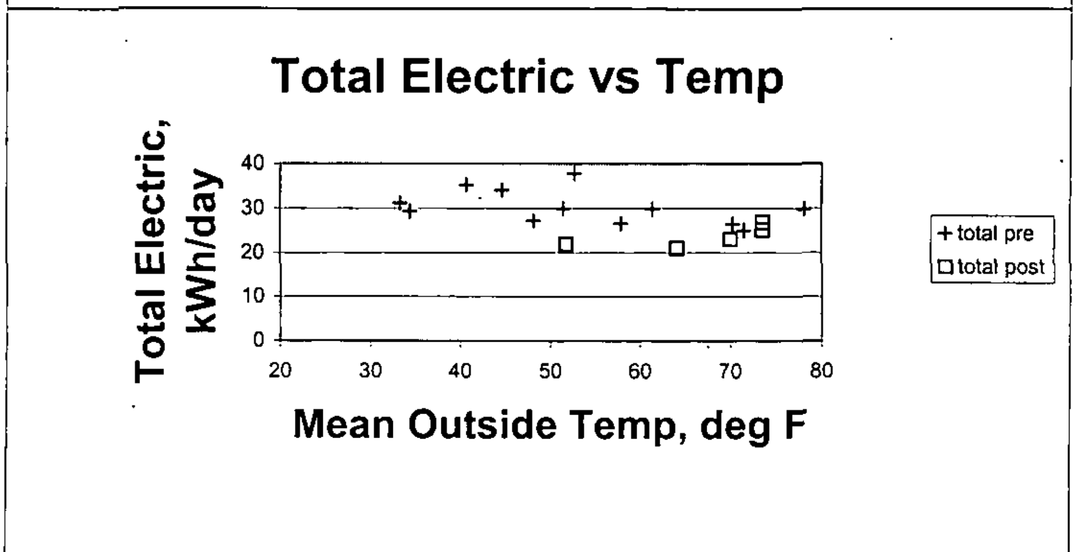


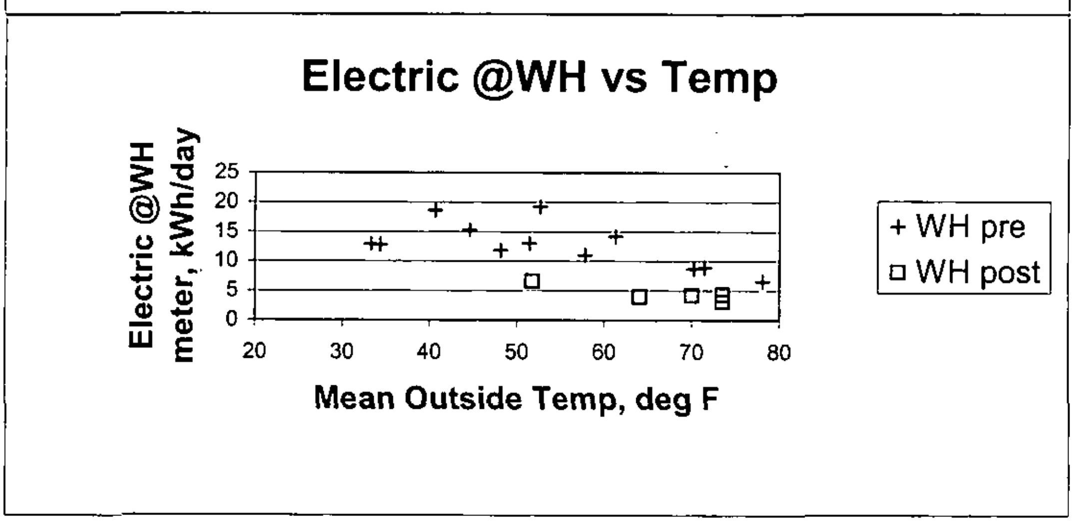




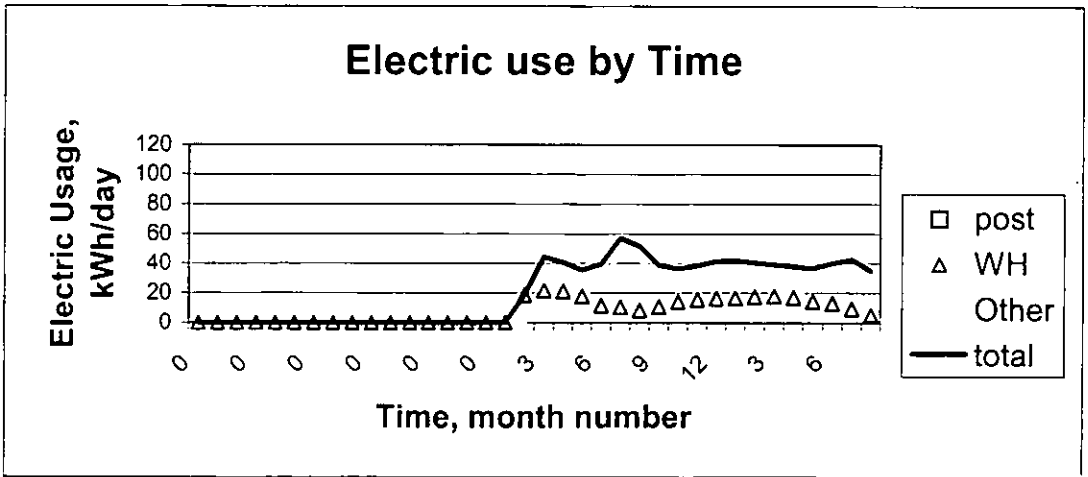
Name	JULIA WILLIAMS		10 months post	8.94 pre kwh/d
Account	251803172534		36 months total	3.88 post kwh/d
Date retro	04/01/00 latest bill	08/25/00	36 months WH	5.06 sav kwh/d

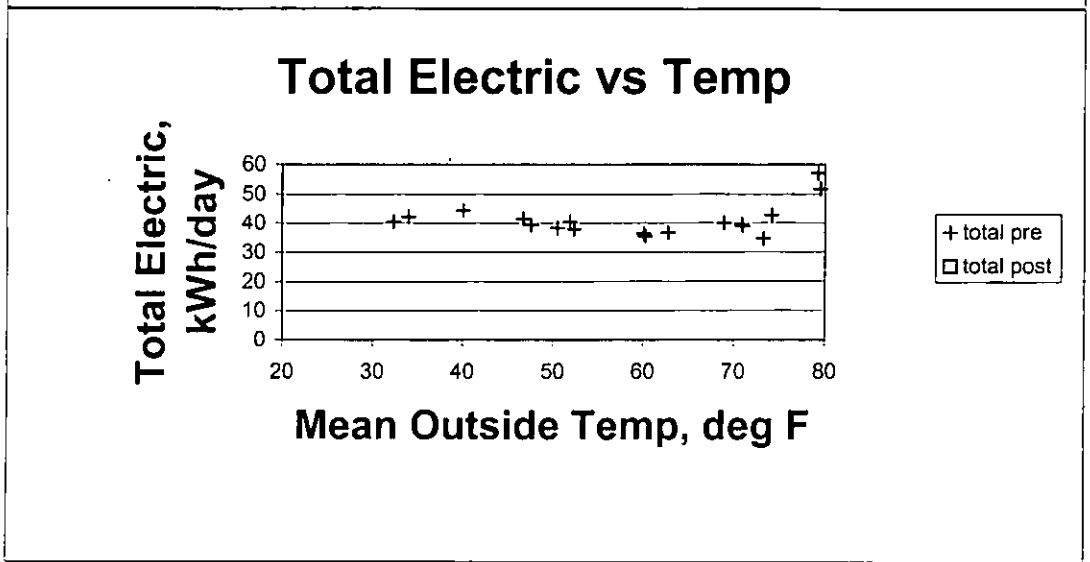


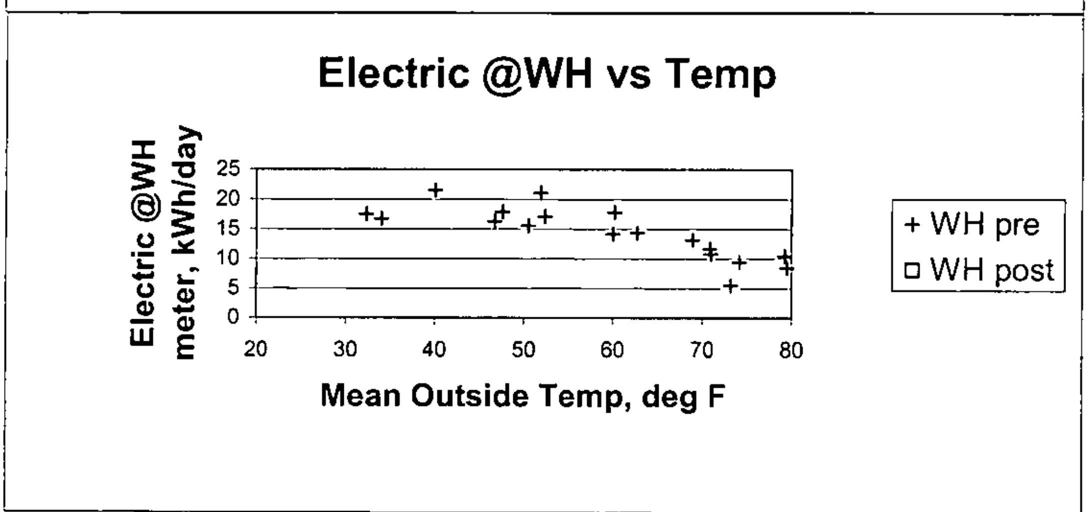




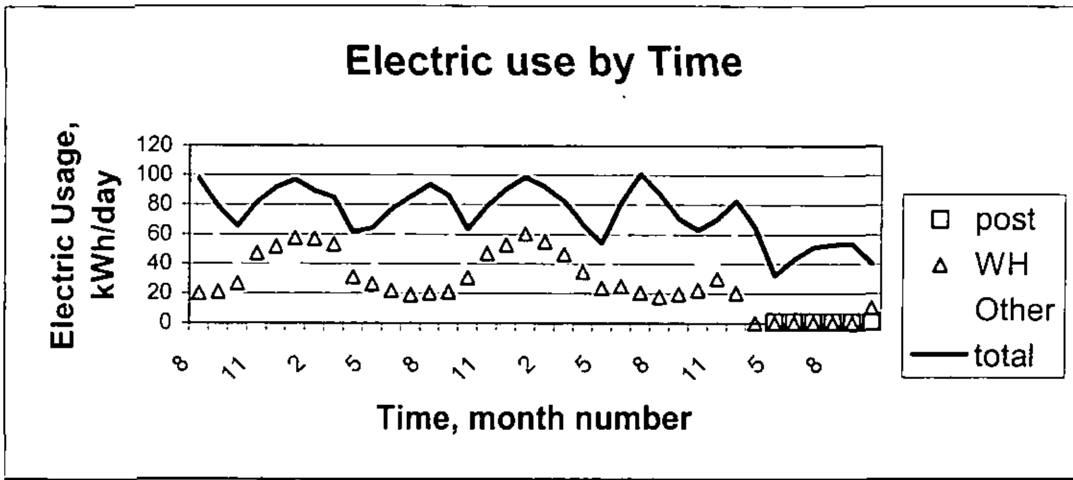
Name	DAWN CULLUM			0 months post	11.56	pre kwh/d
Account	401606639532			19 months total	NA	post kwh/d
Date retro	09/06/00	latest bill	08/24/00	19 months WH	NA	sav kwh/d

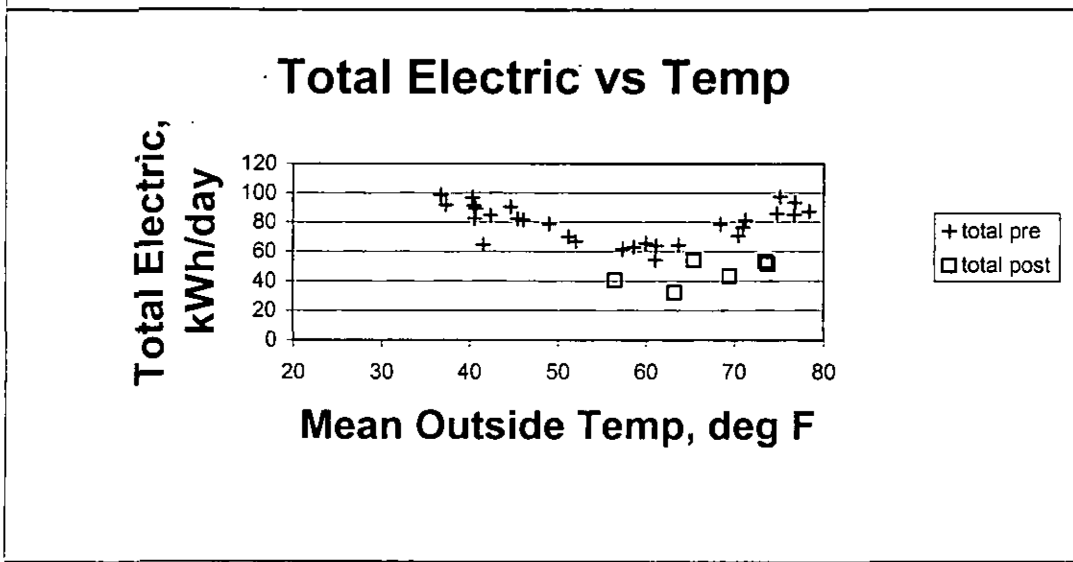


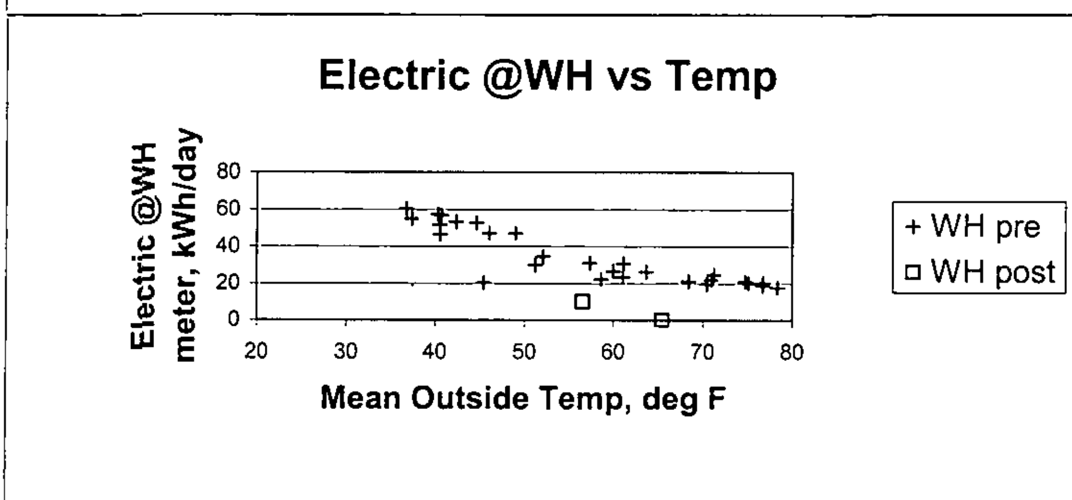




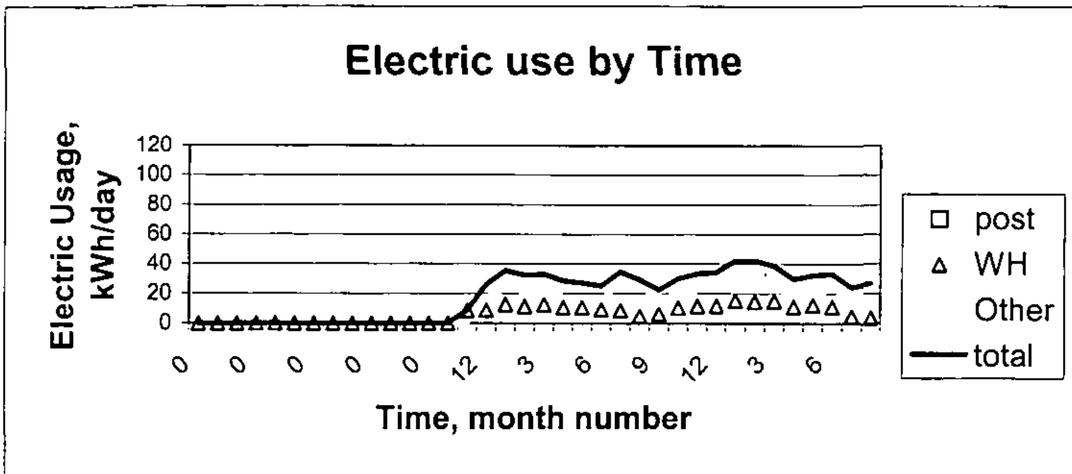
Name DONALD F FORTE 6 months post 22.36 pre kwh/d
Account 351740656043 36 months total 0.04 post kwh/d
Date retro 05/04/00 latest bill 10/25/00 31 months WH 22.32 sav kwh/d

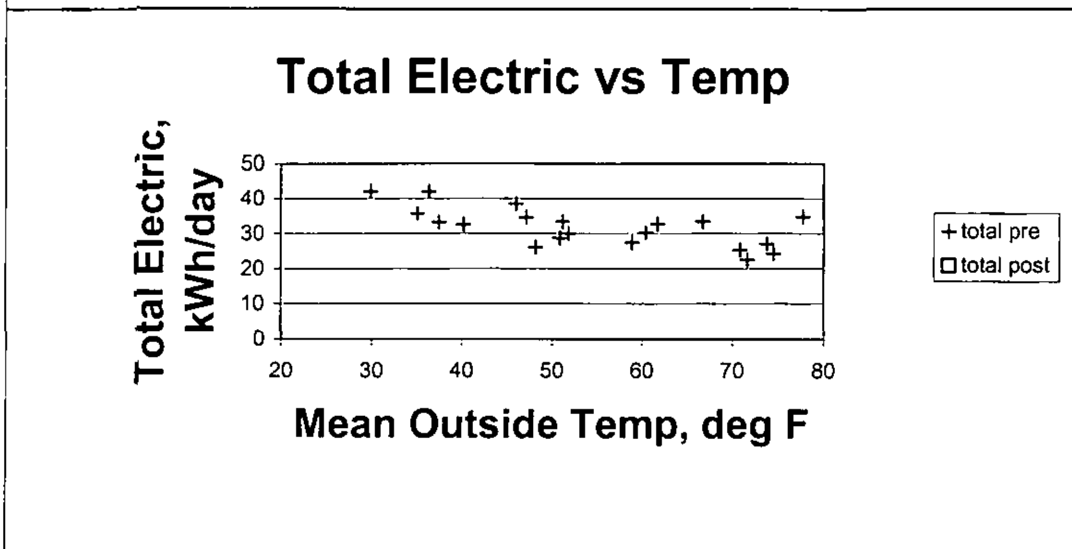


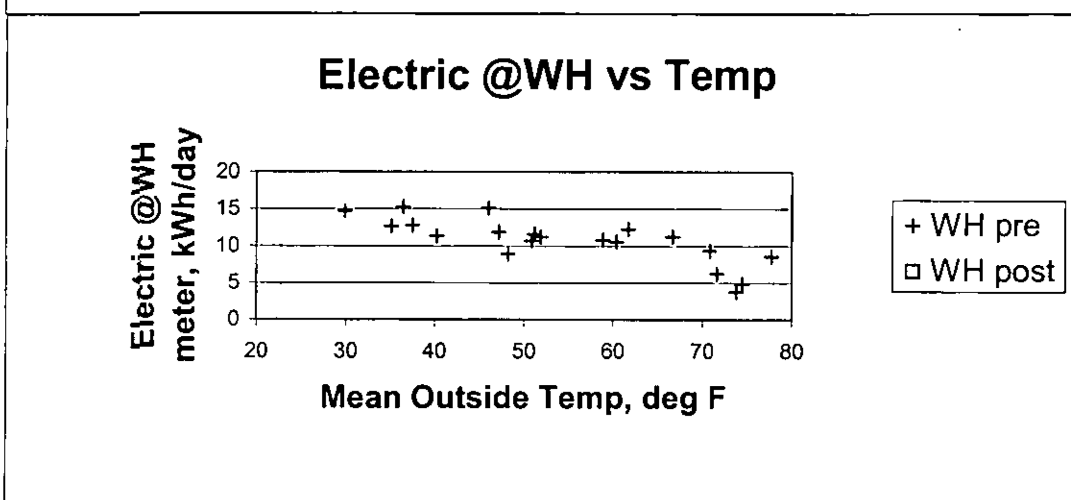




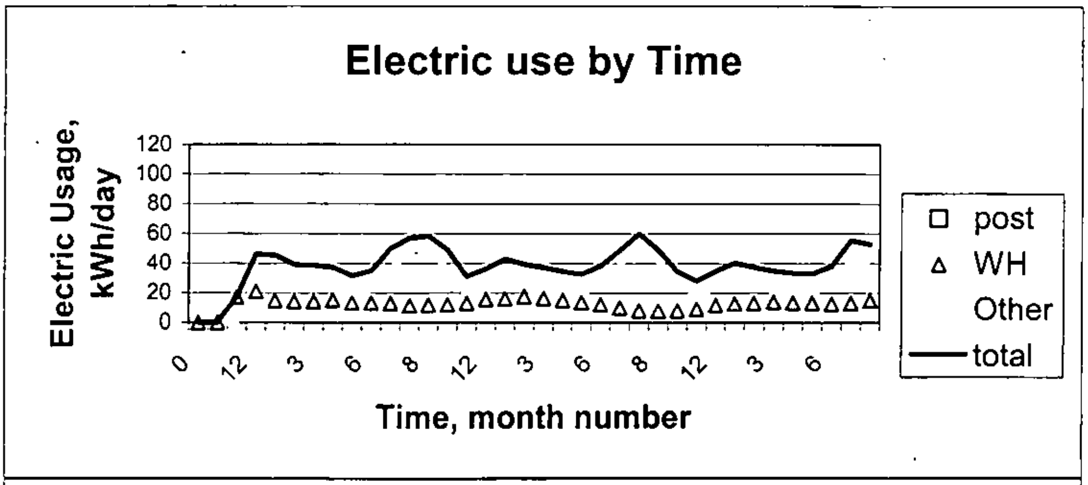
Name	SALLIE HERWIG			0 months post		7.96 pre kwh/d
Account	351342536031			22 months total	NA	post kwh/d
Date retro	09/01/00 latest bill	08/18/00		22 months WH	NA	sav kwh/d

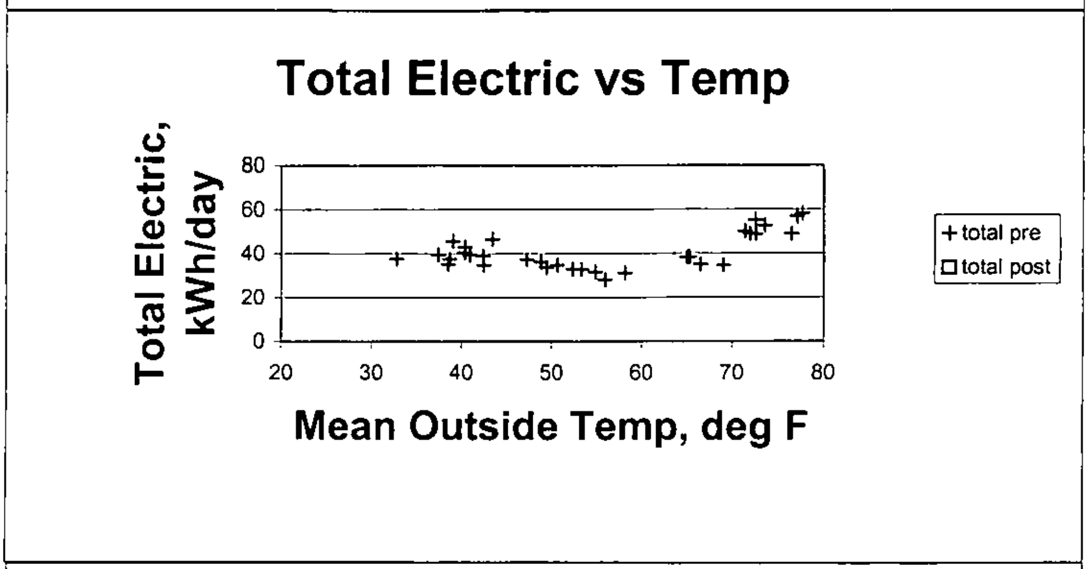


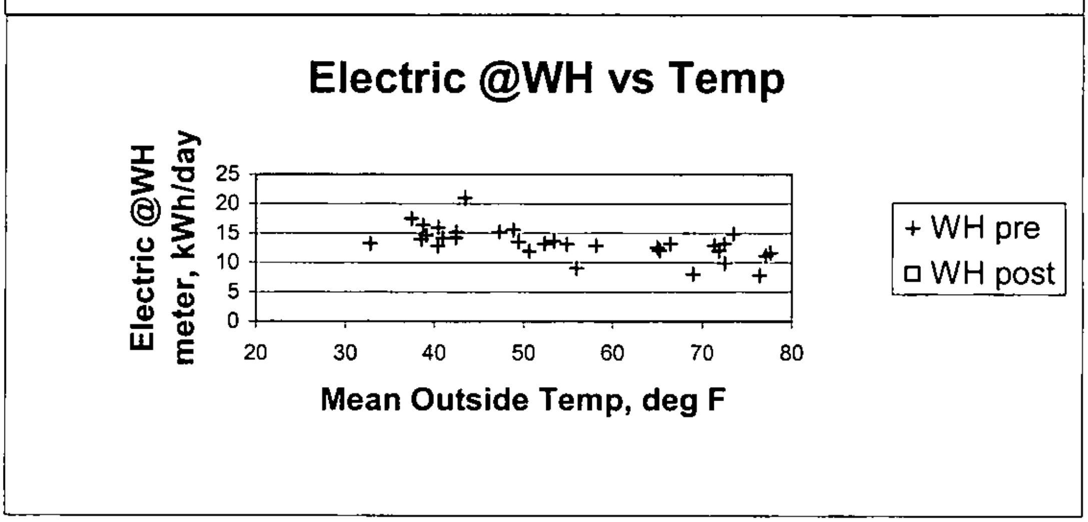




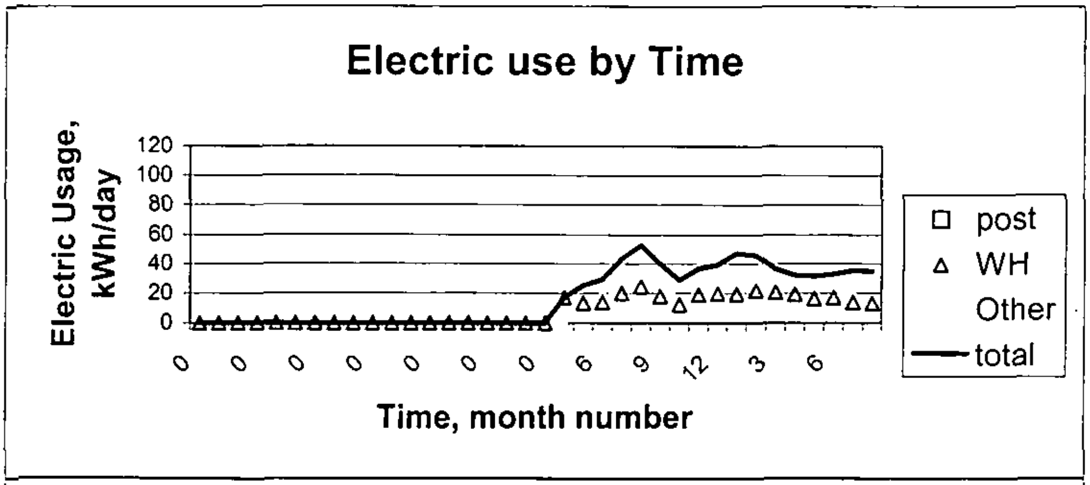
Name	OLIVER KENNEDY		0	months post	11.30	pre kwh/d
Account	550166020010		34	months total	NA	post kwh/d
Date retro	09/01/00 latest bill	08/01/00	34	months WH	NA	sav kwh/d

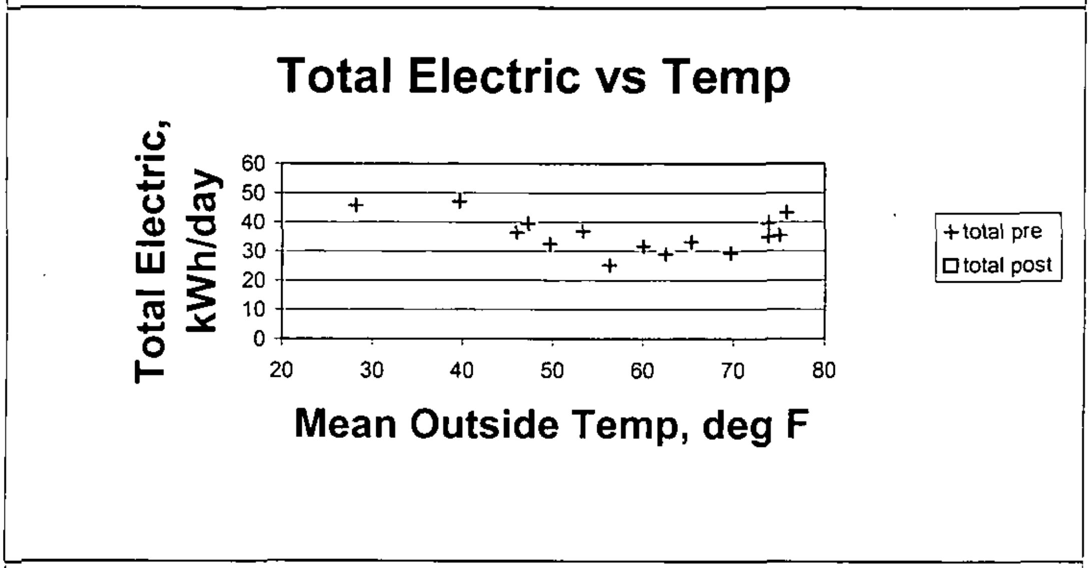


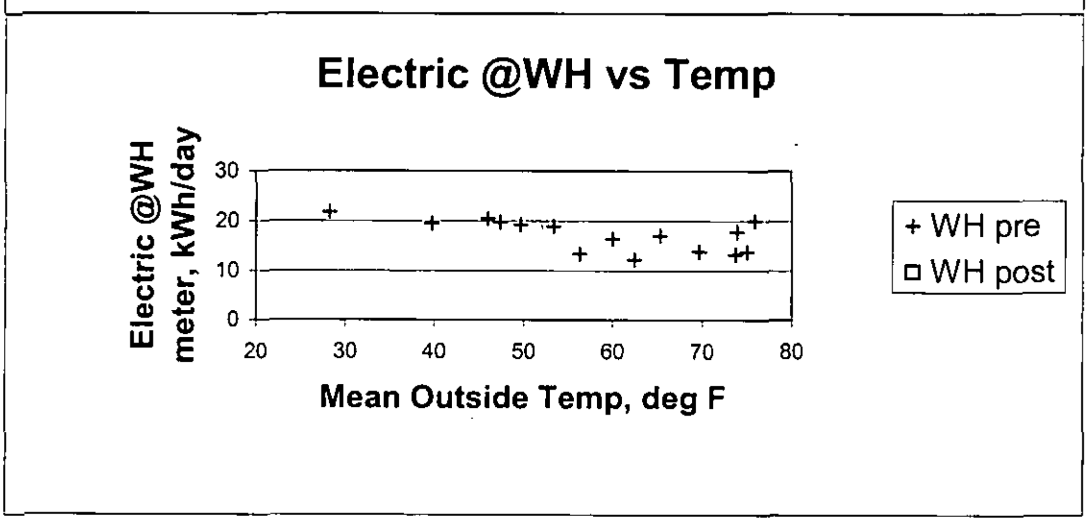




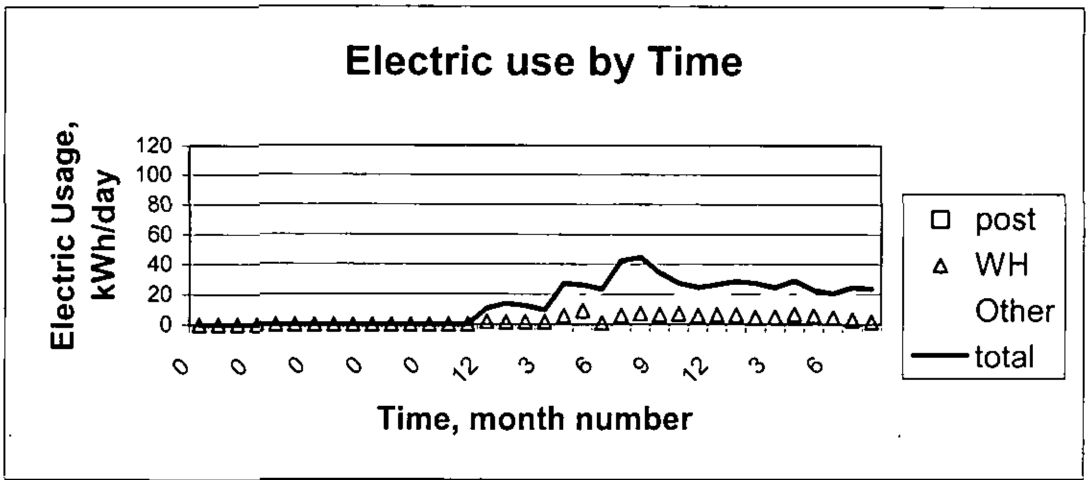
Name	BRUCE R MOWDAY		0	months post	16.55	pre kwh/d
Account	351040003037		17	months total	NA	post kwh/d
Date retro	09/01/00 latest bill	08/15/00	17	months WH	NA	sav kwh/d

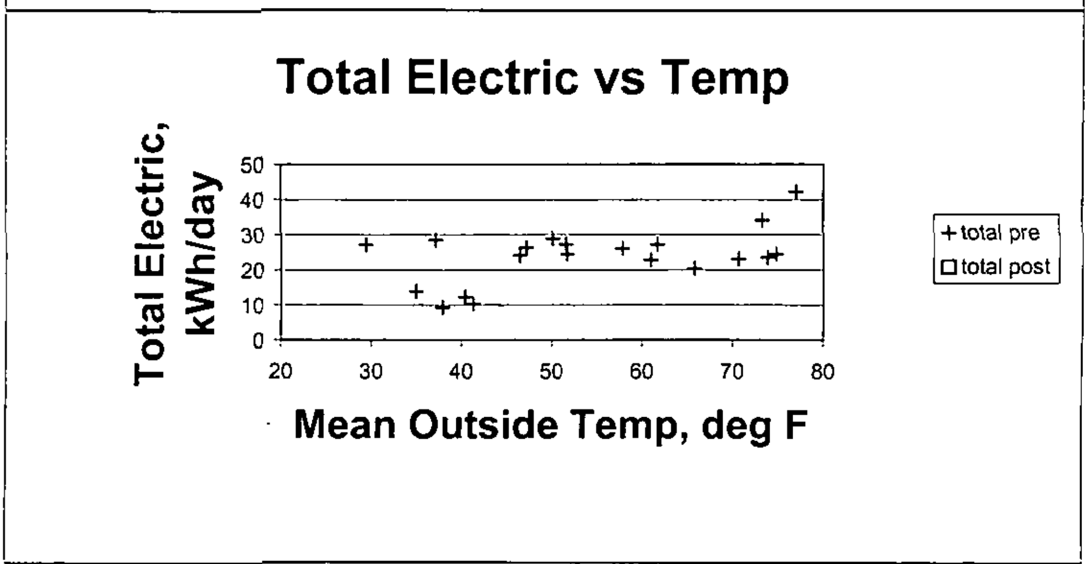


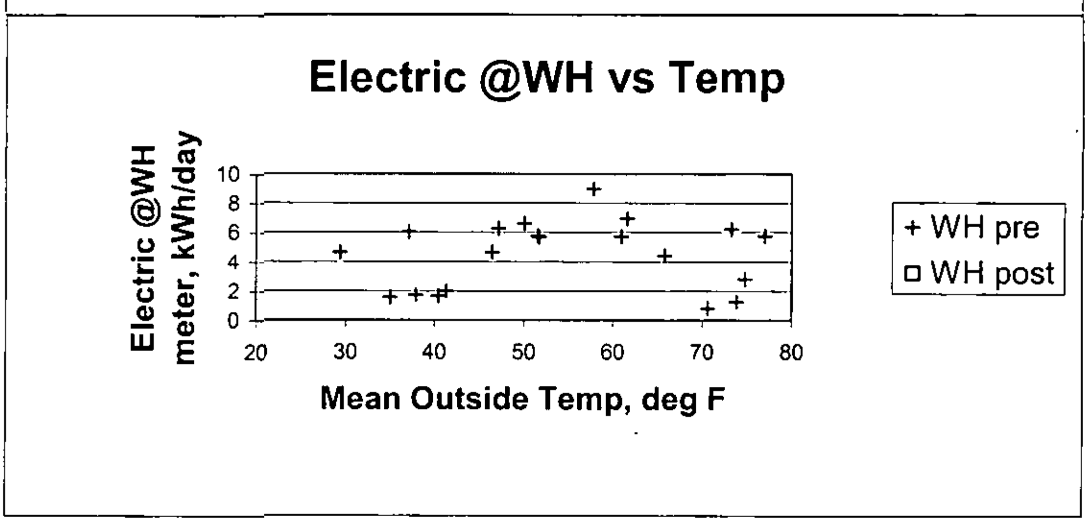




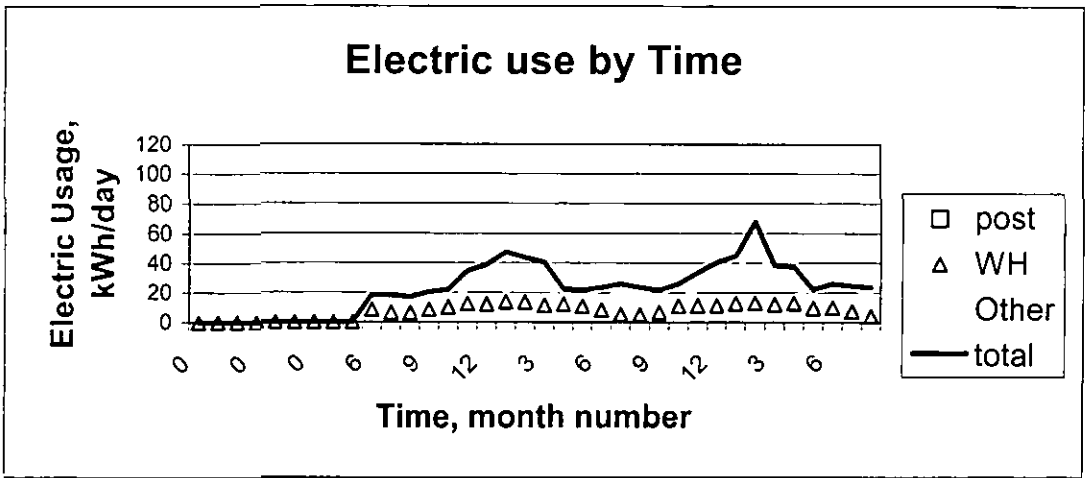
Name	SHERRY ROBINSON		0 months post		4.55	pre kwh/d
Account	401218817518		21 months total	NA		post kwh/d
Date retro	08/25/00 latest bill	08/17/00	21 months WH	NA		sav kwh/d

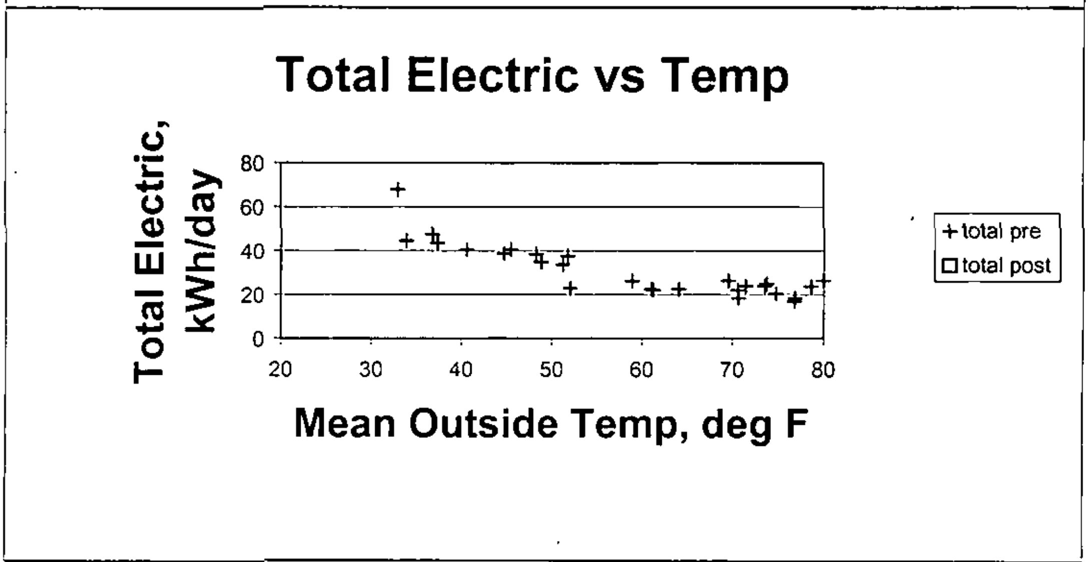


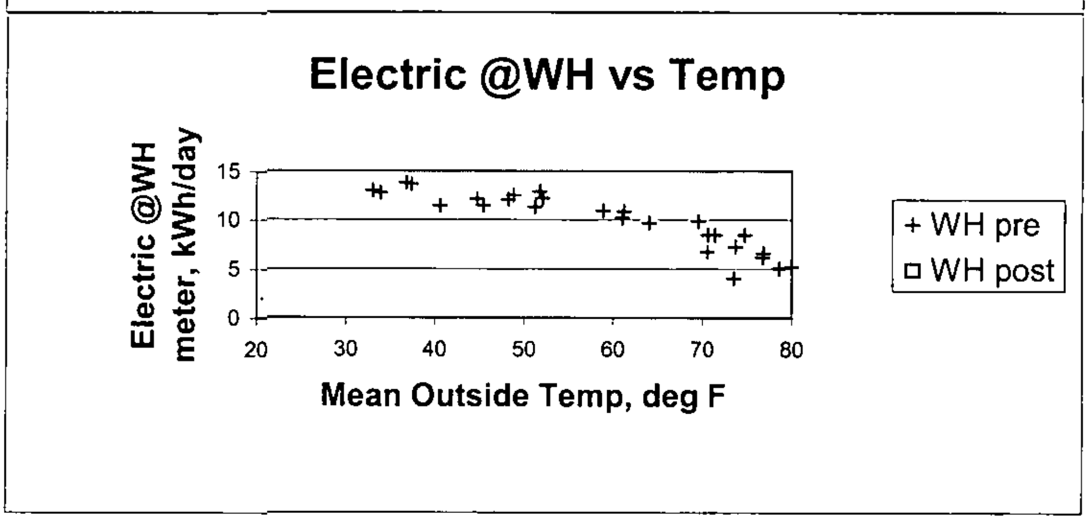




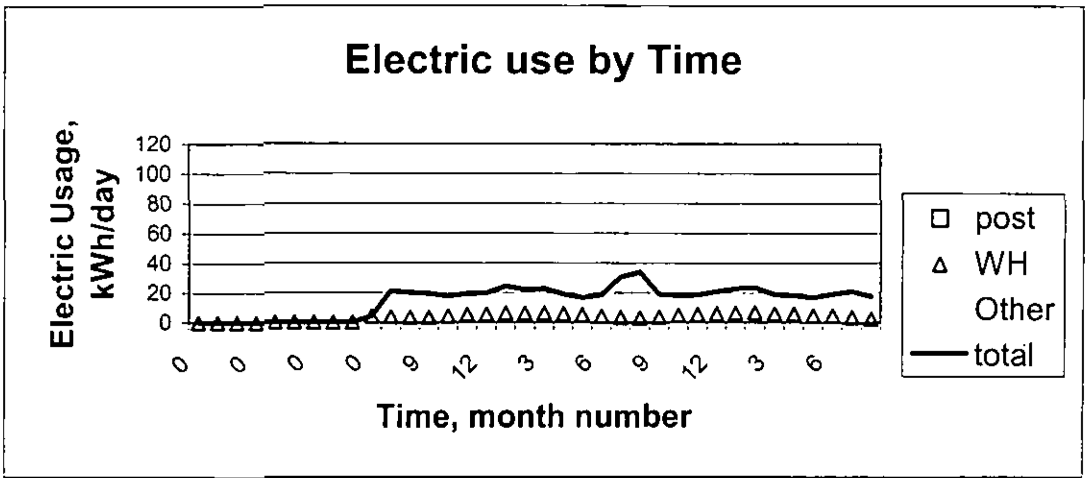
Name	VANESSA TAMMARO			0 months post		7.62	pre kwh/d
Account	351743488535			27 months total	NA		post kwh/d
Date retro	08/25/00	latest bill	08/25/00	27 months WH	NA		sav kwh/d

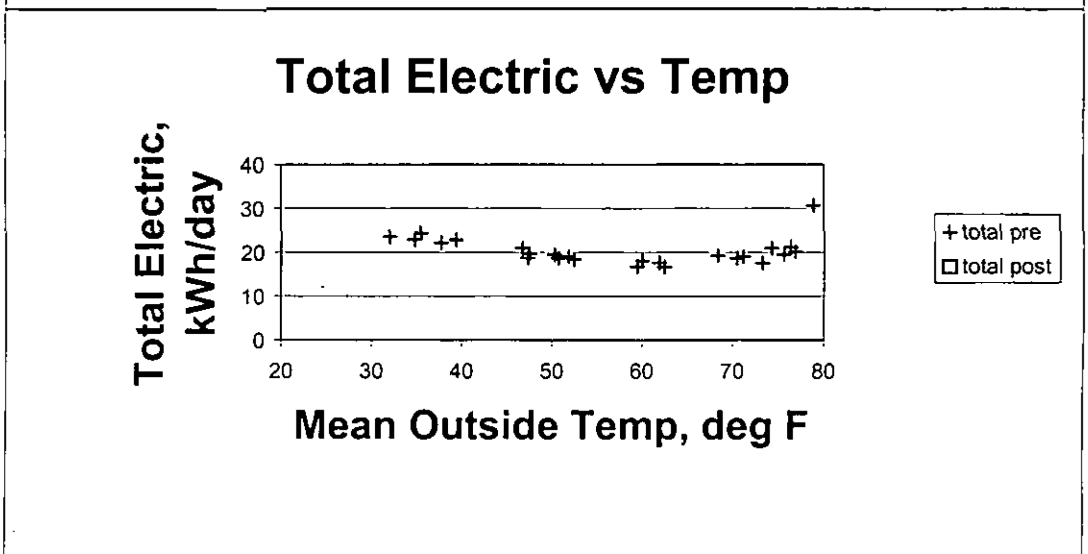


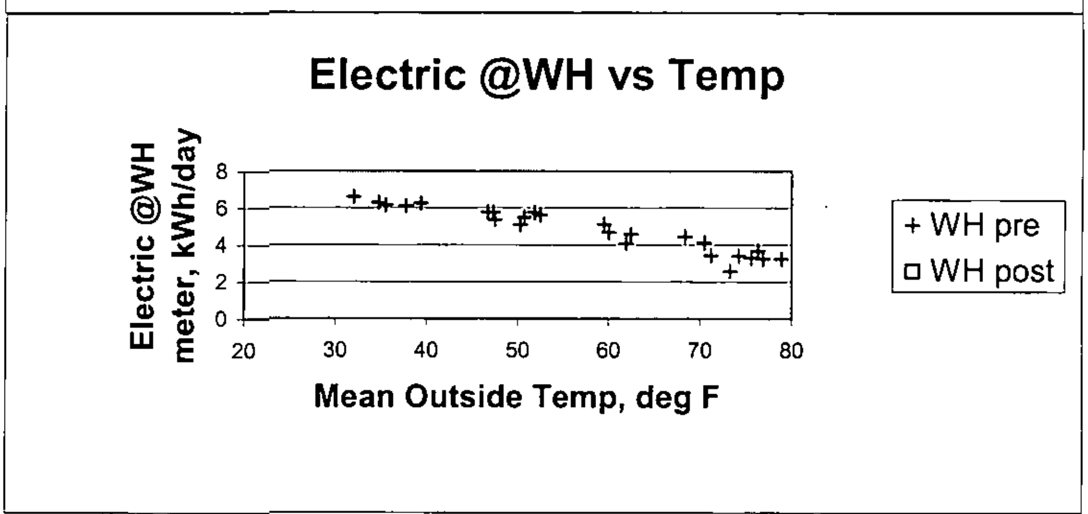




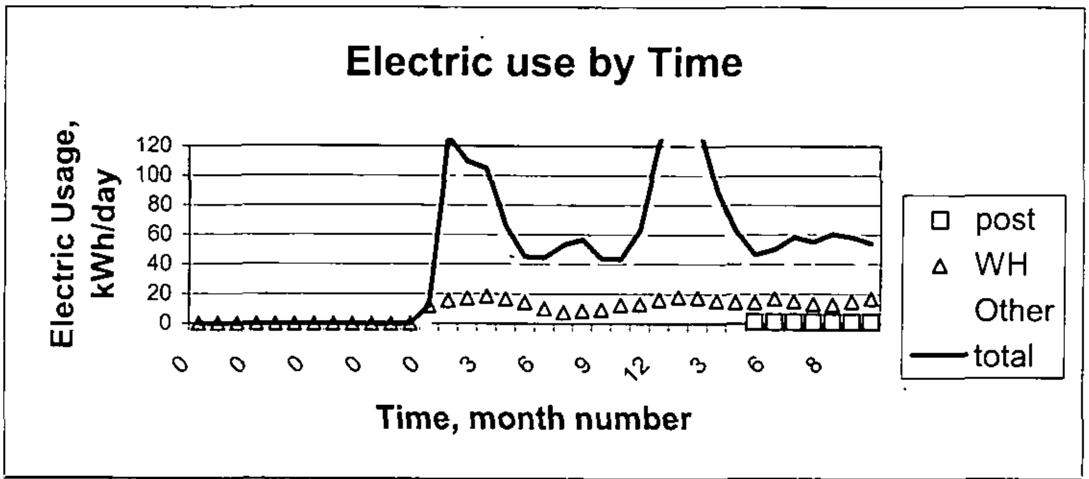
Name	MONICA A WINCE			0 months post		3.65 pre kwh/d
Account	401504858010			27 months total	NA	post kwh/d
Date retro	09/06/00 latest bill	08/22/00		27 months WH	NA	sav kwh/d

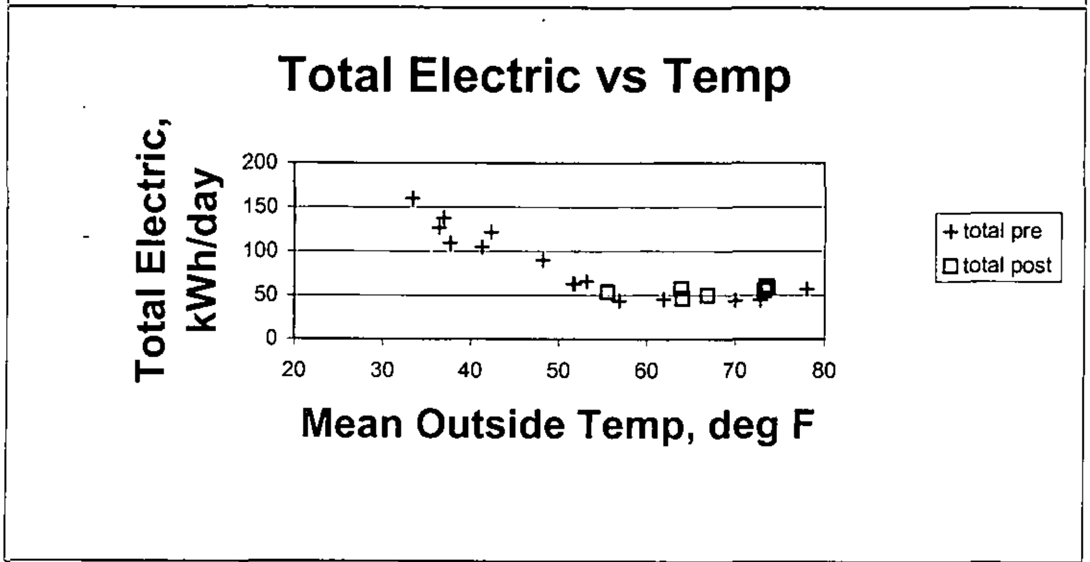


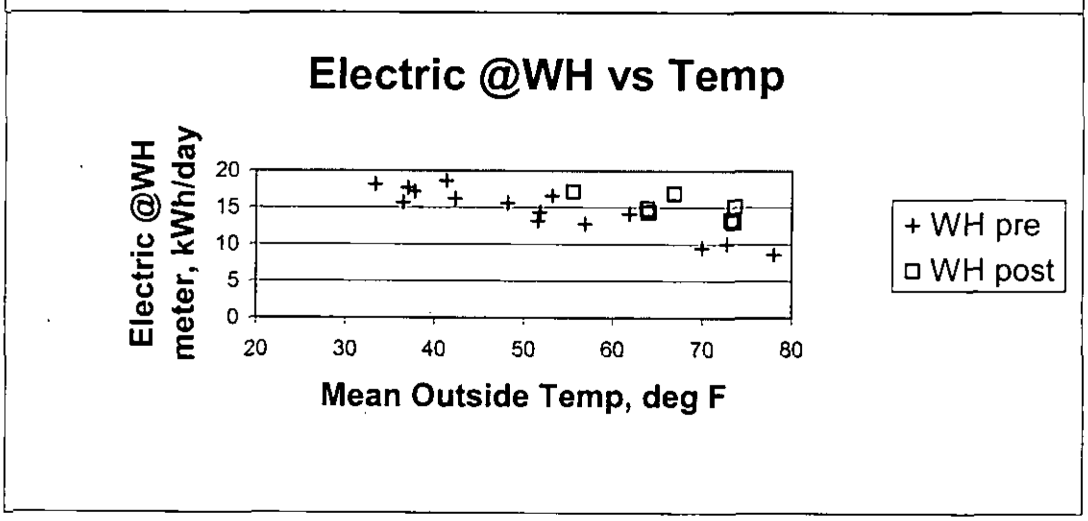




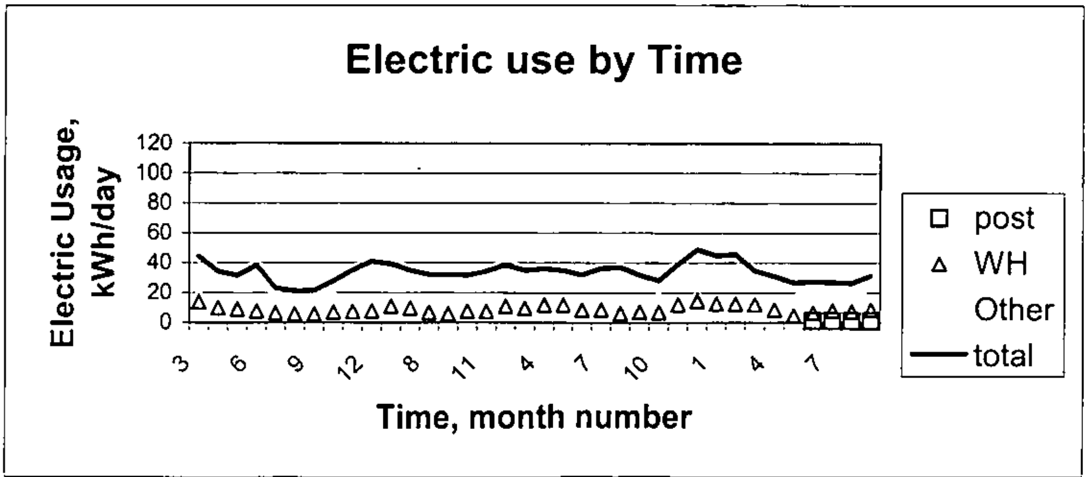
Name	ANNA D VISCICHINI		7 months post	9.97	pre kwh/d
Account	351940389528		24 months total	14.57	post kwh/d
Date retro	05/24/00 latest bill	10/30/00	24 months WH	-4.59	sav kwh/d

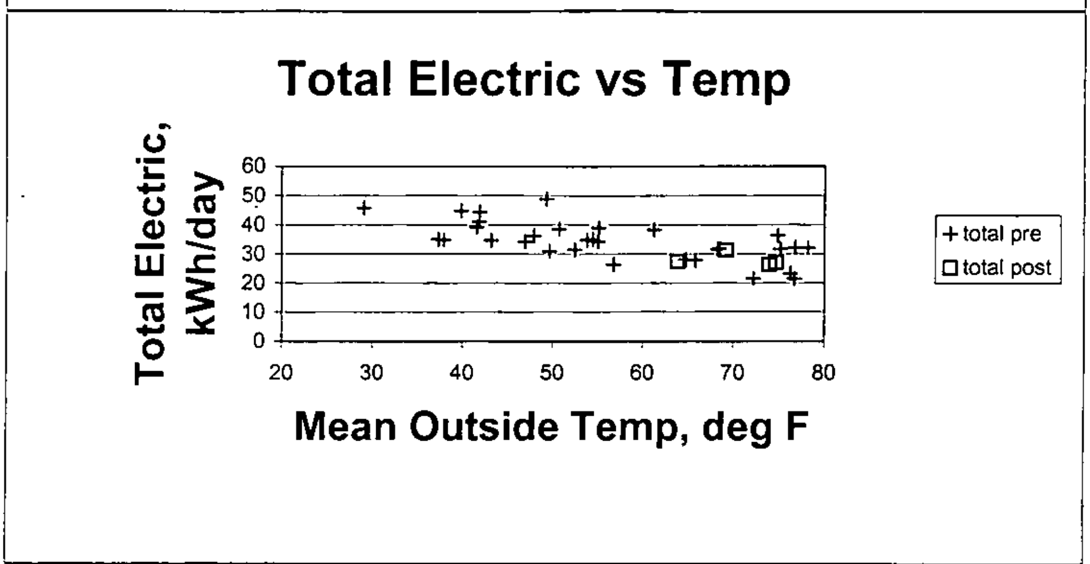


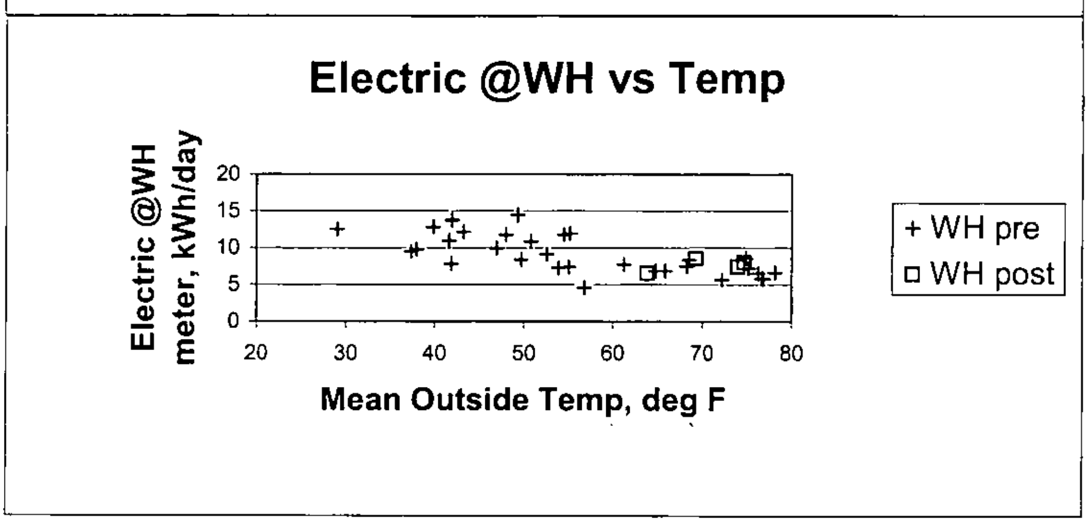




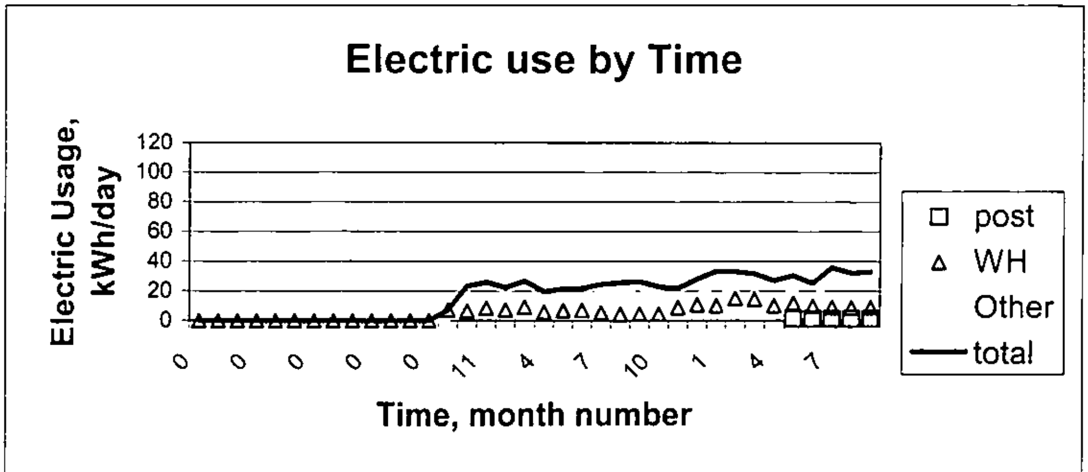
Name	MRS JO ANN SMALL		4 months post	6.90 pre kwh/d
Account	350640395017		36 months total	7.63 post kwh/d
Date retro	05/23/00 latest bill	09/11/00	36 months WH	-0.73 sav kwh/d

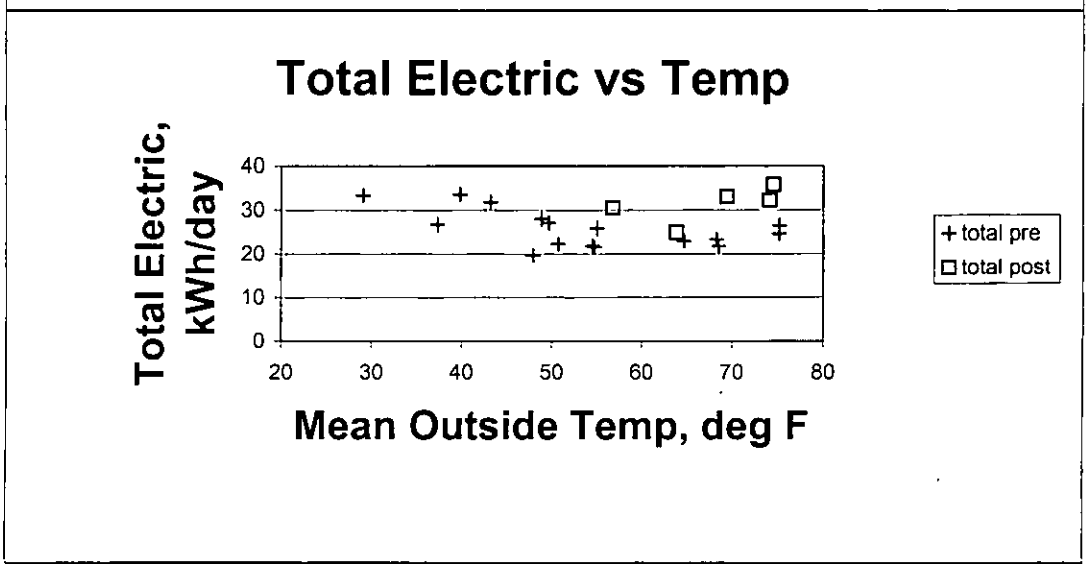


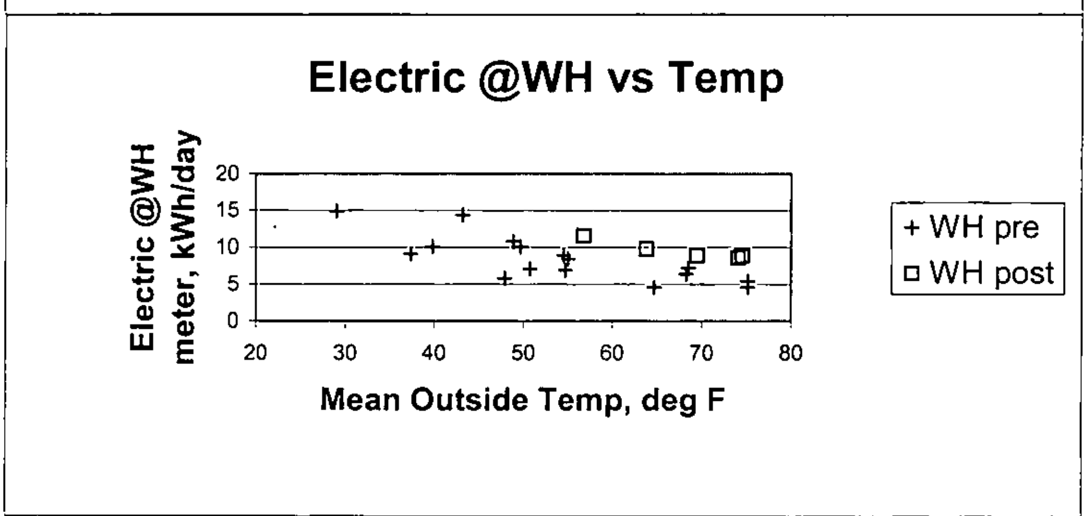




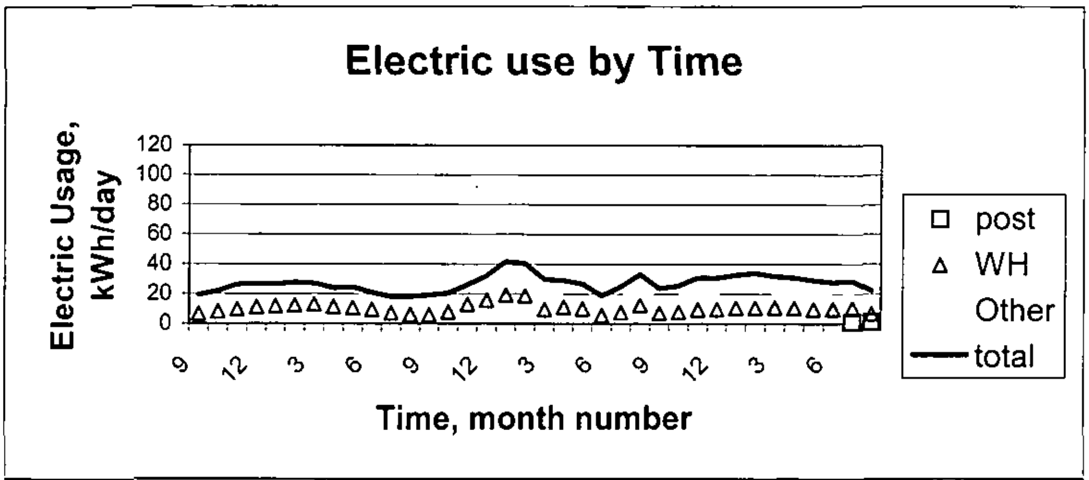
Name	PETER MARINACCIO		5 months post	5.38	pre kwh/d
Account	400606696062		23 months total	9.02	post kwh/d
Date retro	04/10/00 latest bill	09/08/00	23 months WH	-3.64	sav kwh/d

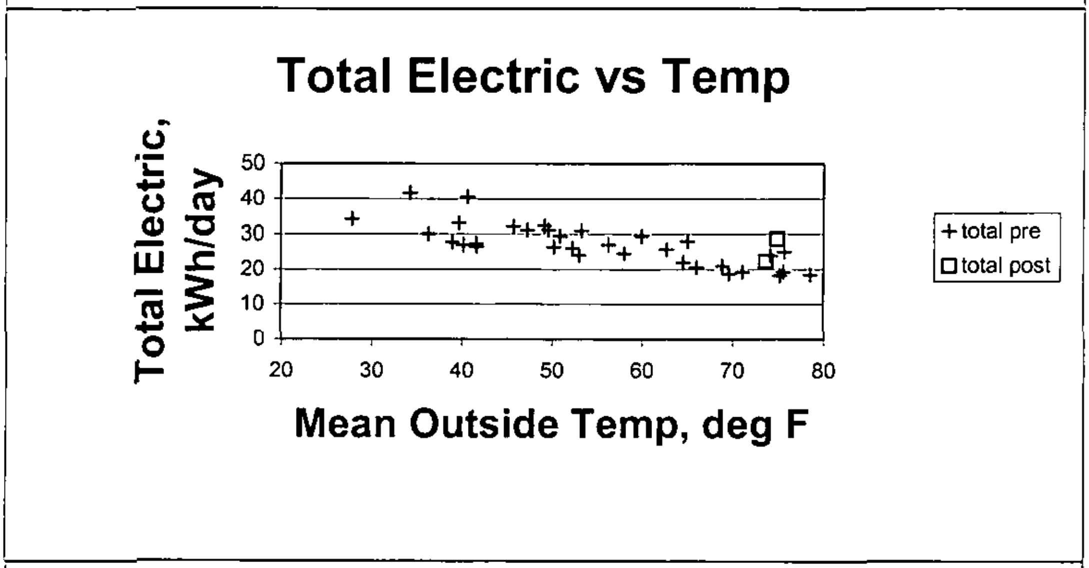


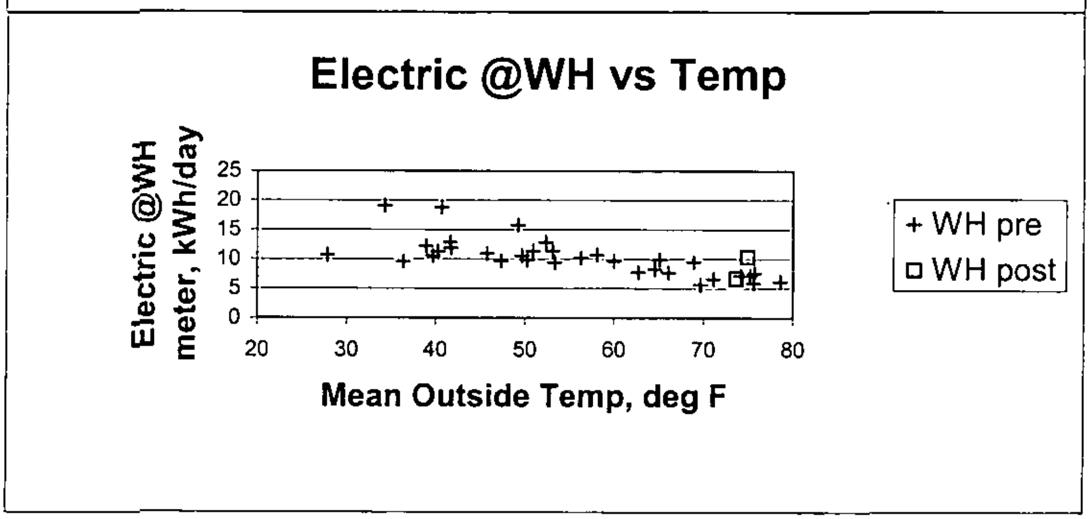




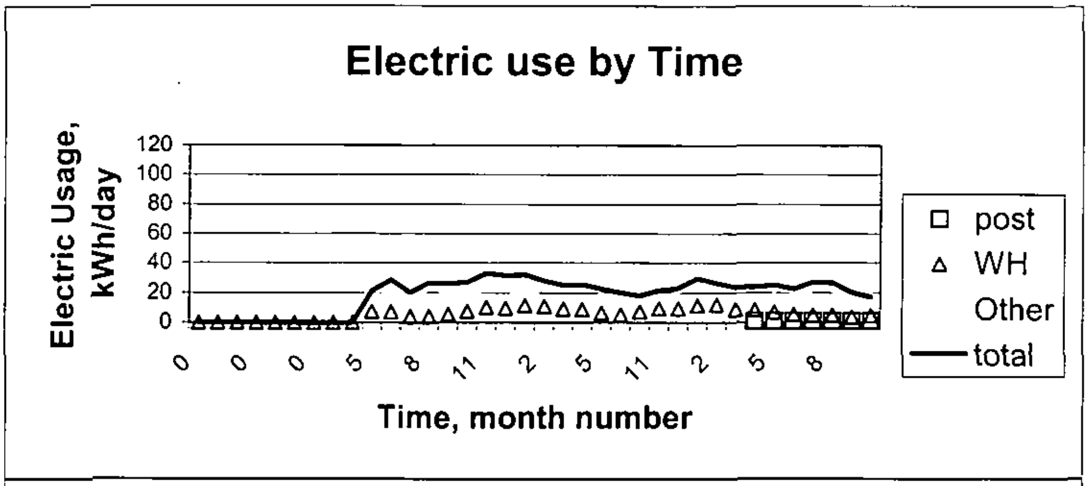
Name	ROBERT DAVID ASHLEIGH			2 months post	7.79	pre kwh/d
Account	501014618521			36 months total	8.49	post kwh/d
Date retro	06/21/00	latest bill	08/14/00	36 months WH	-0.70	sav kwh/d

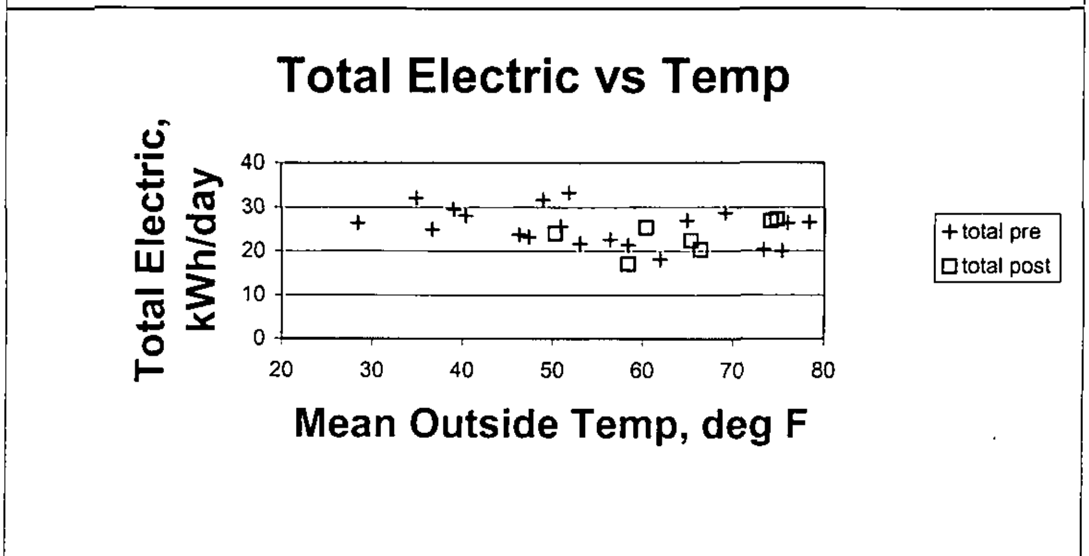


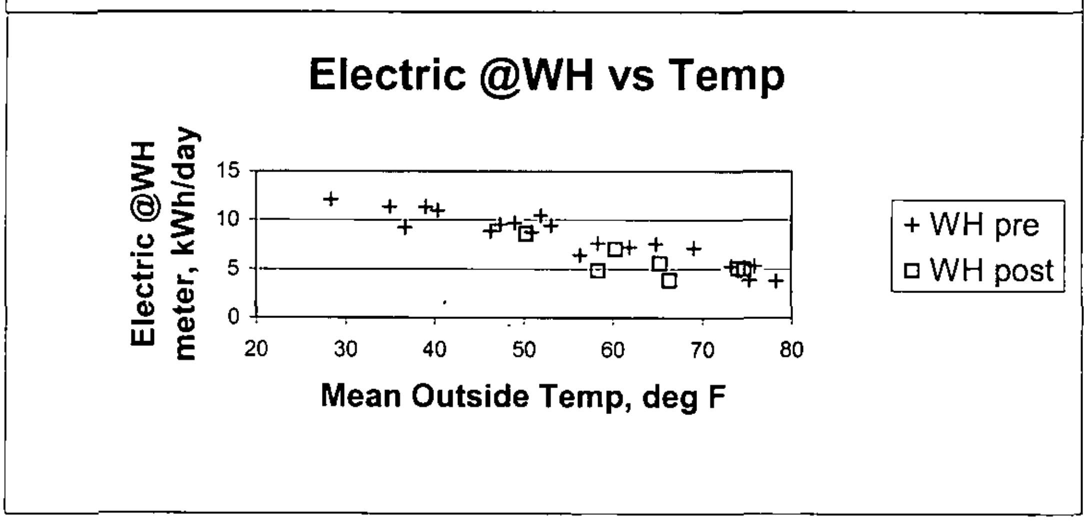




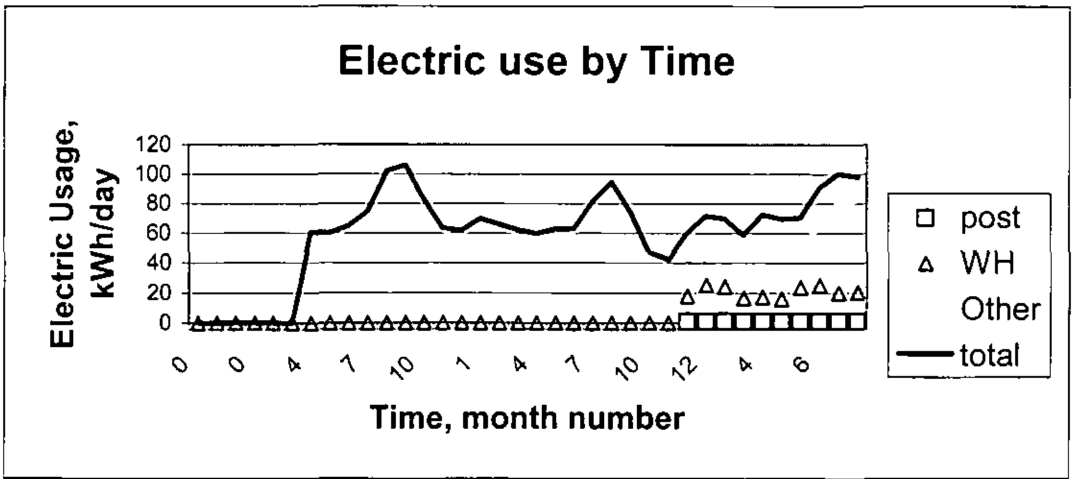
Name	KEVIN JONES		7 months post	5.73 pre kwh/d
Account	401102485562		27 months total	5.30 post kwh/d
Date retro	04/03/00 latest bill	10/17/00	27 months WH	0.43 sav kwh/d

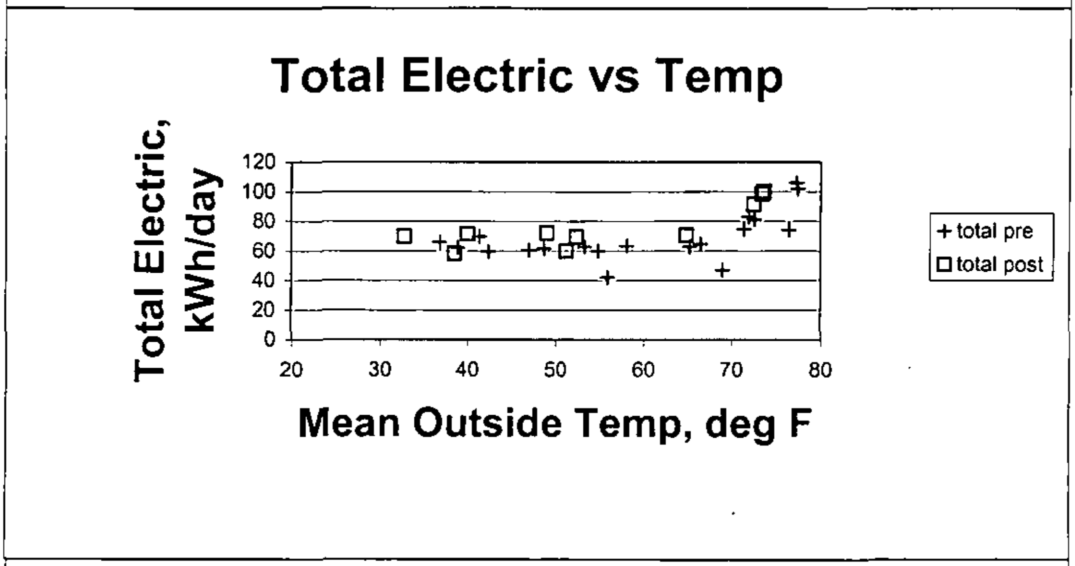


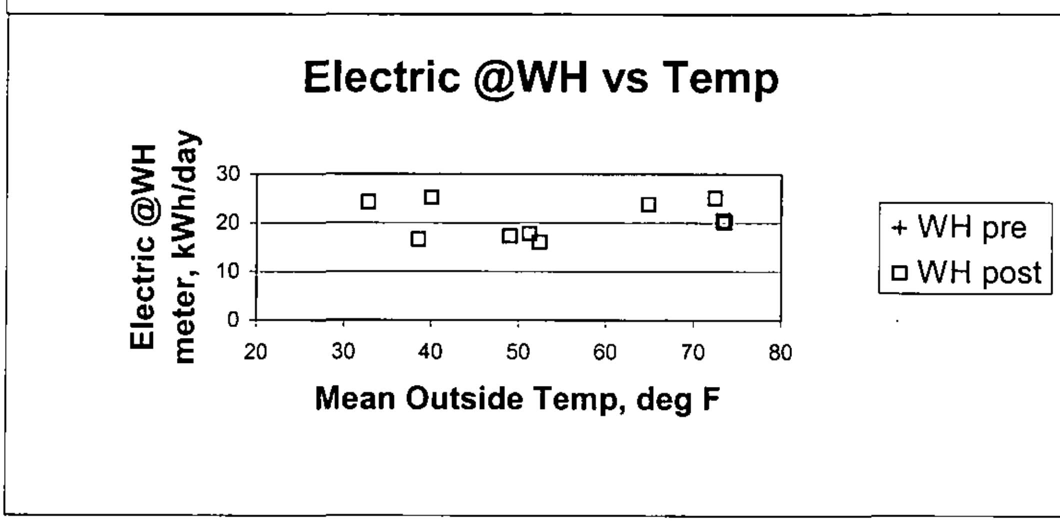




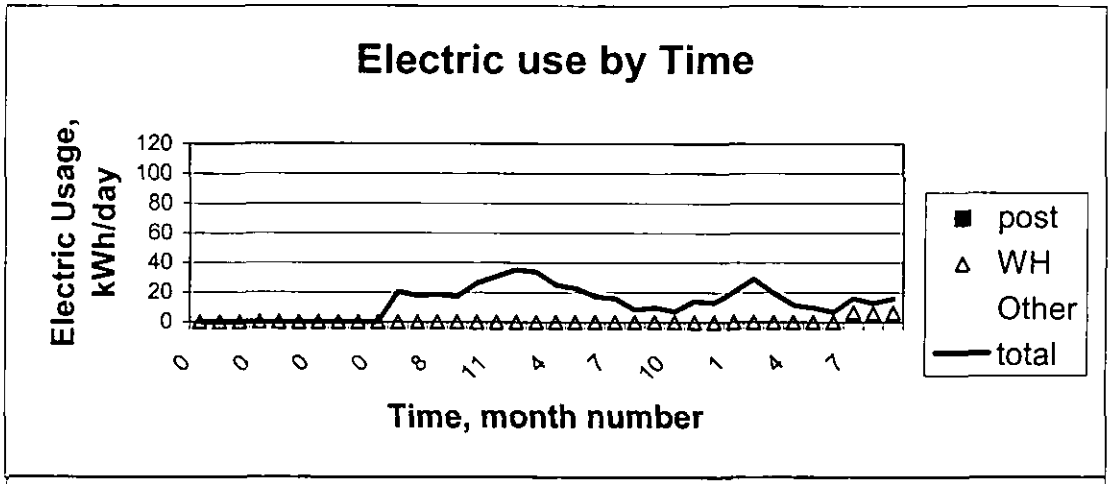
Name	ENNIO PONTARELLI		10 months post	NA		pre kwh/d
Account	270137399811		30 months total		22.33	post kwh/d
Date retro	10/30/99 latest bill	08/31/00	10 months WH	NA		sav kwh/d

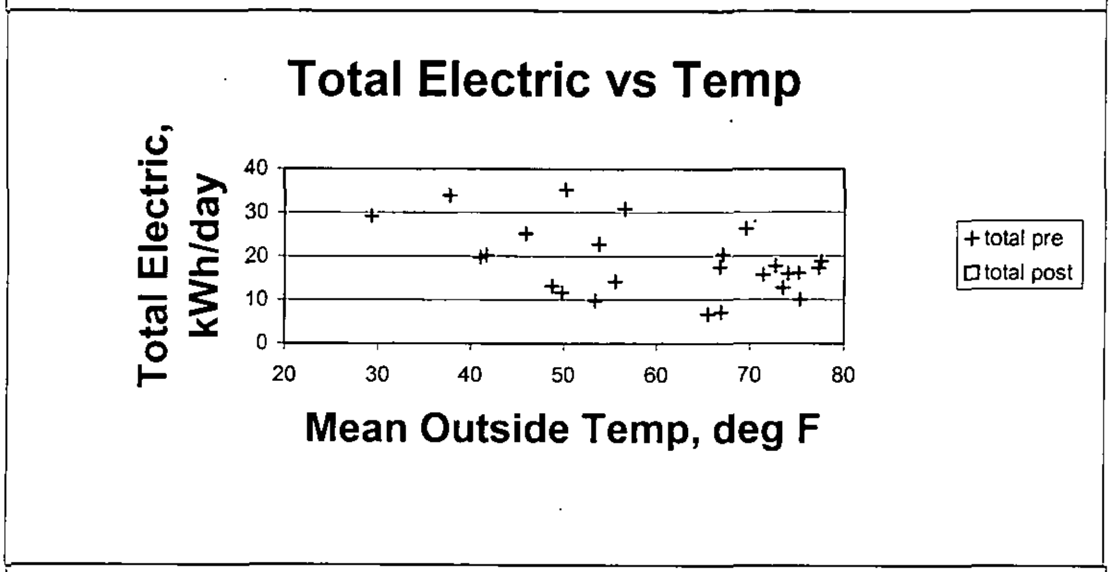


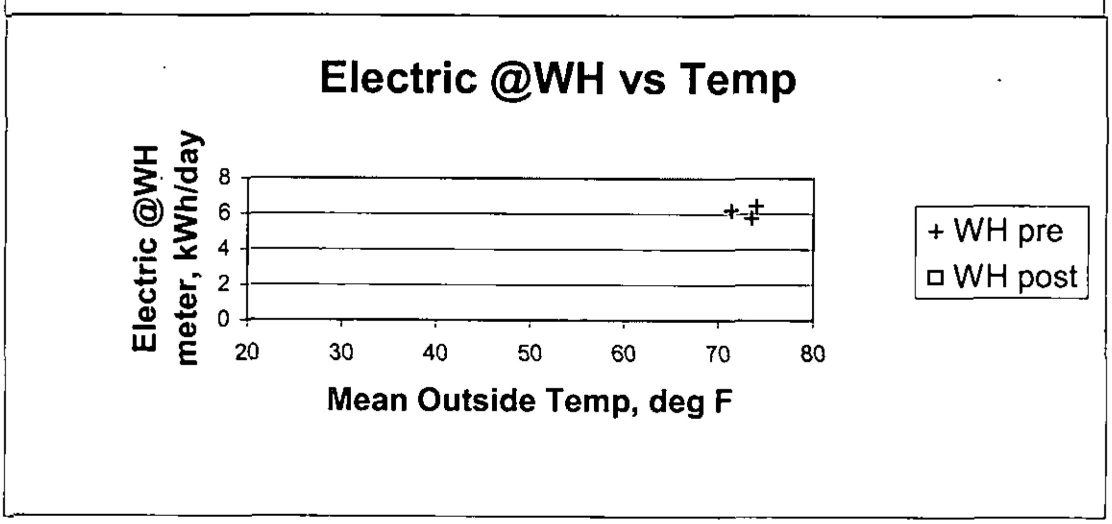




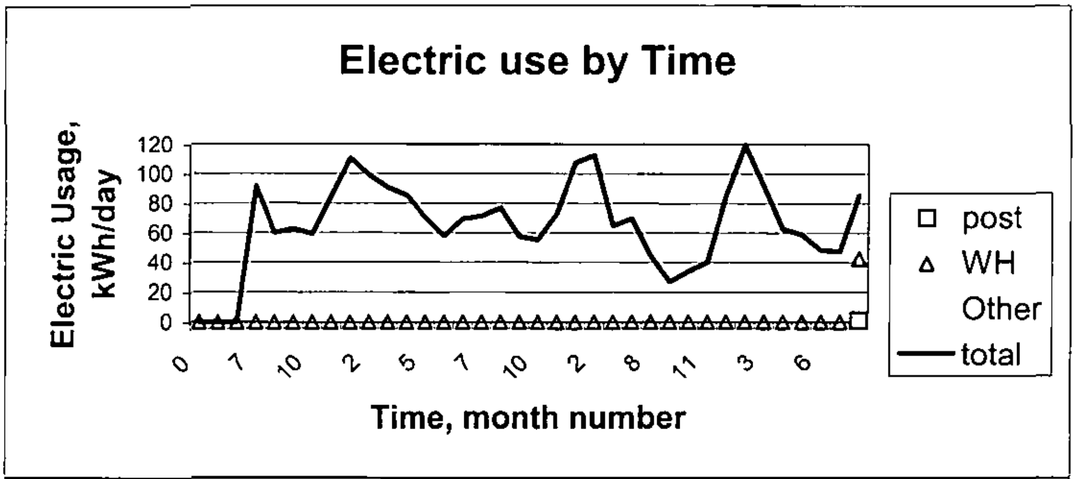
Name	KIMBERLY JONES		0 months post		6.13 pre kwh/d
Account	250448047655		26 months total	NA	post kwh/d
Date retro	09/08/00 latest bill	09/06/00	3 months WH	NA	sav kwh/d

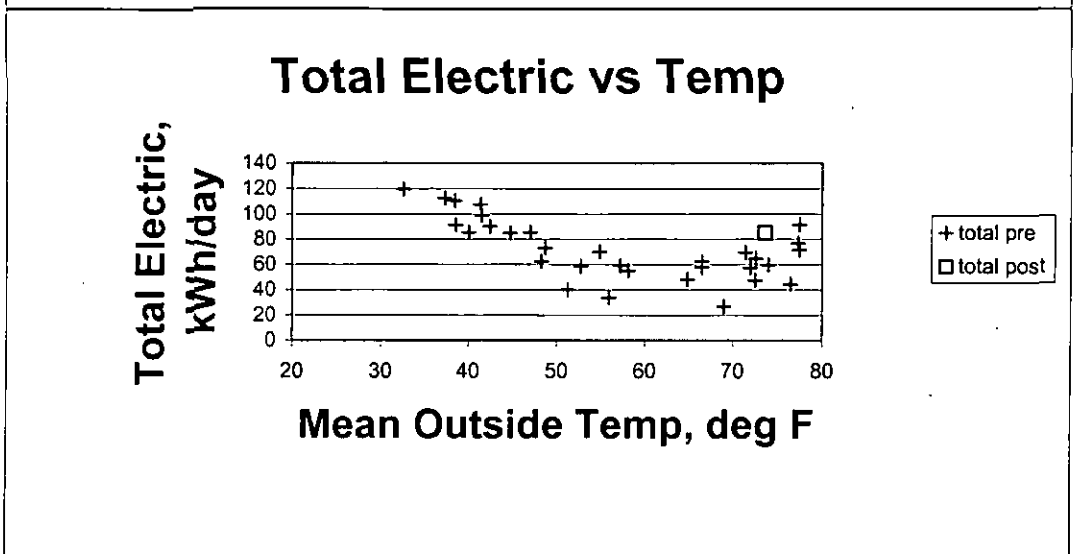


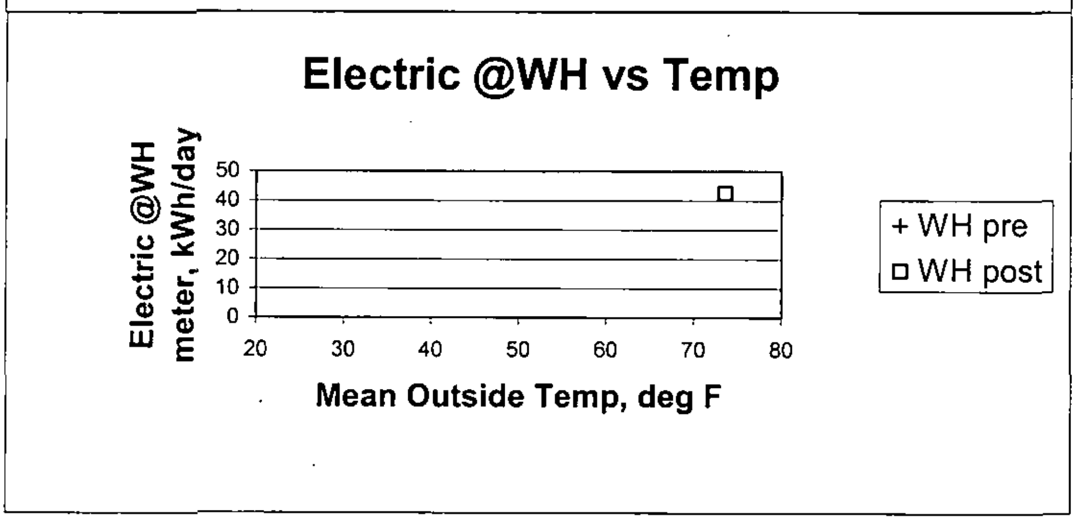




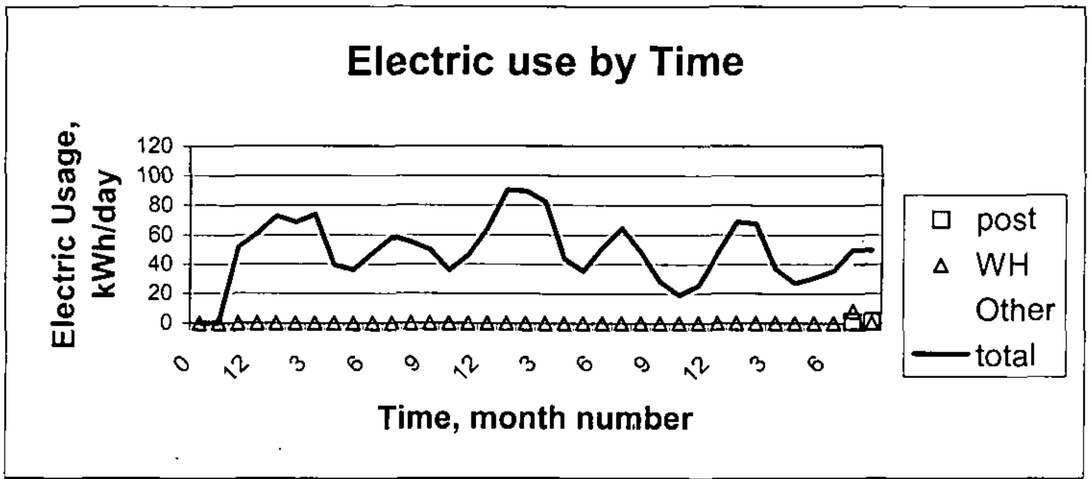
Name	JOSEPH HOFMANN			1	months post	NA	pre kwh/d
Account	350142684025			33	months total	42.51	post kwh/d
Date retro	07/06/00	latest bill	08/01/00	1	months WH	NA	sav kwh/d

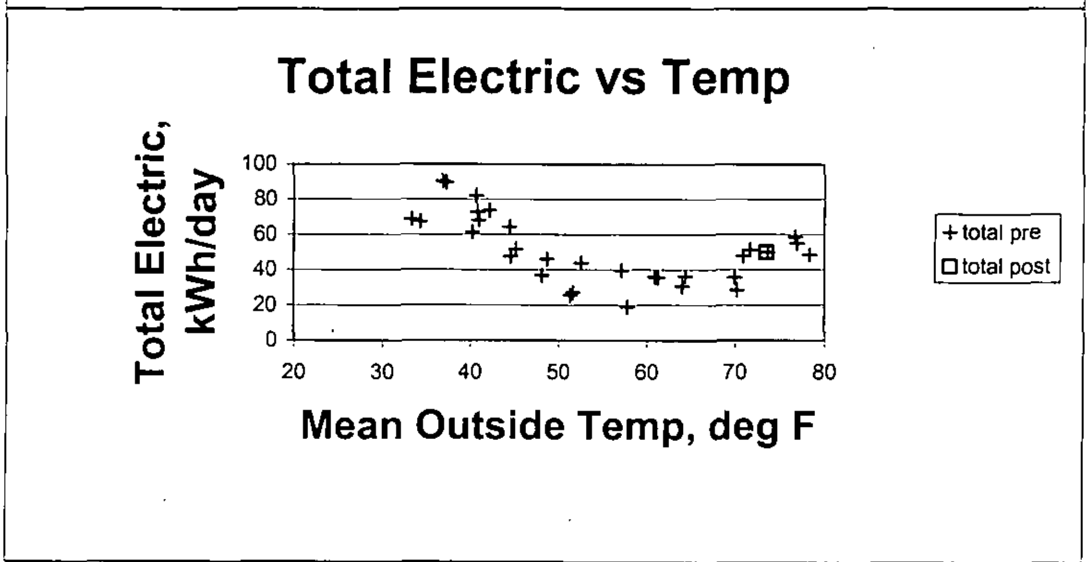


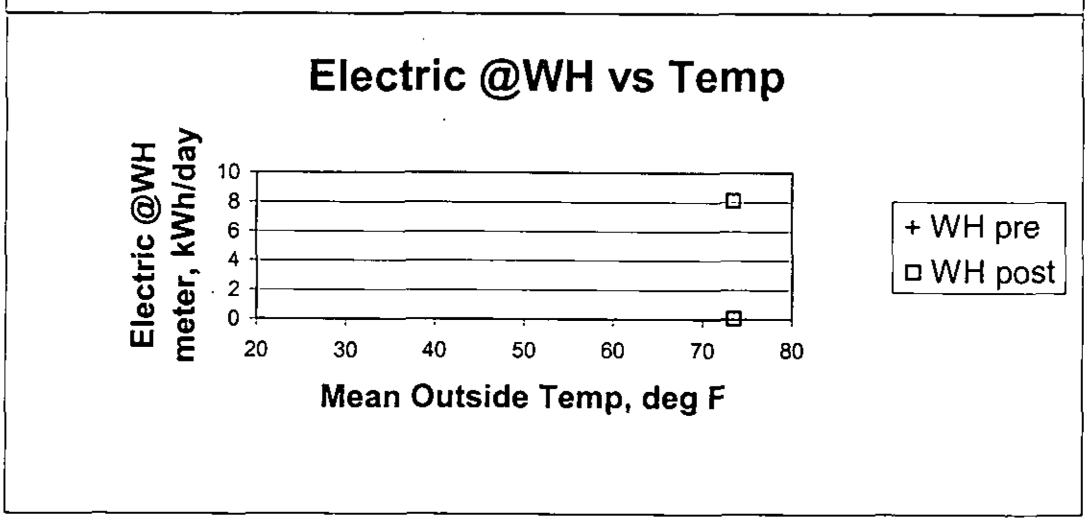




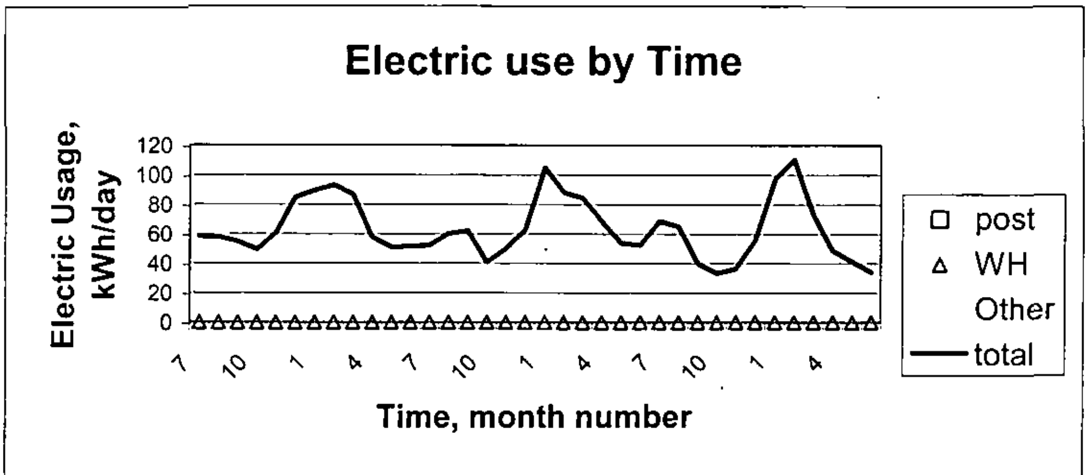
Name	DONALD CACCIATORE			2 months post	NA		pre kwh/d
Account	501850414548			34 months total		4.09	post kwh/d
Date retro	06/28/00	latest bill	08/26/00	2 months WH	NA		sav kwh/d

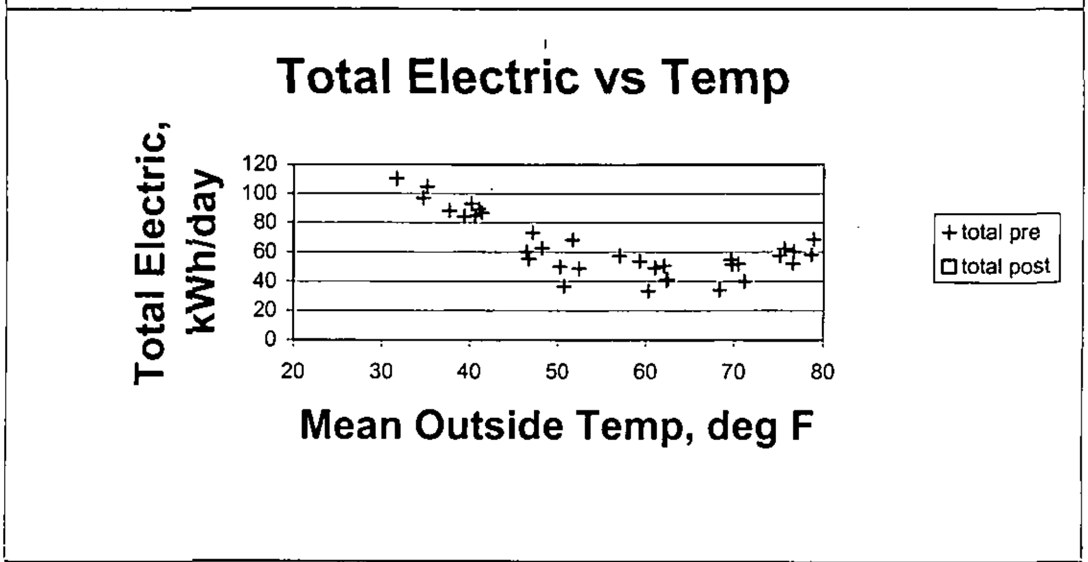


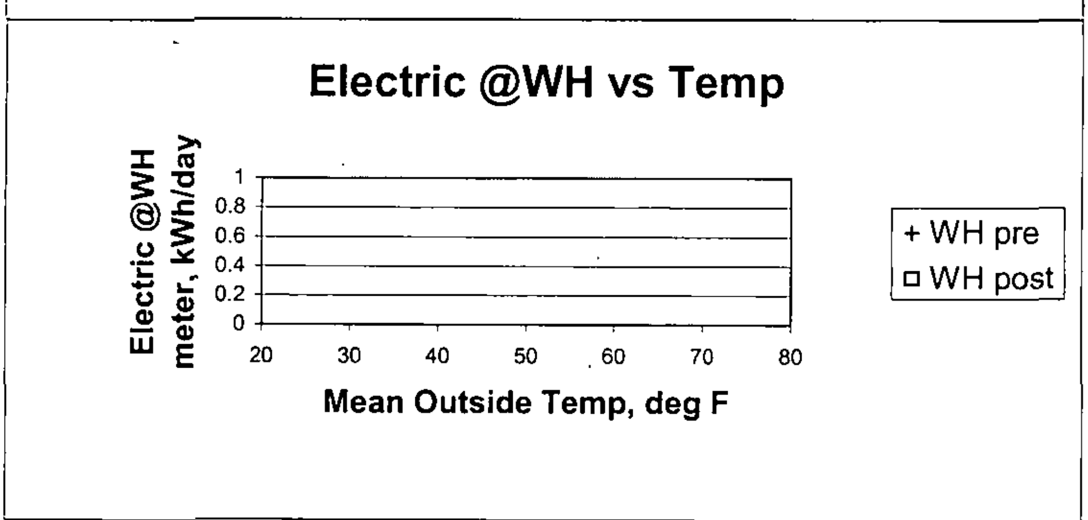




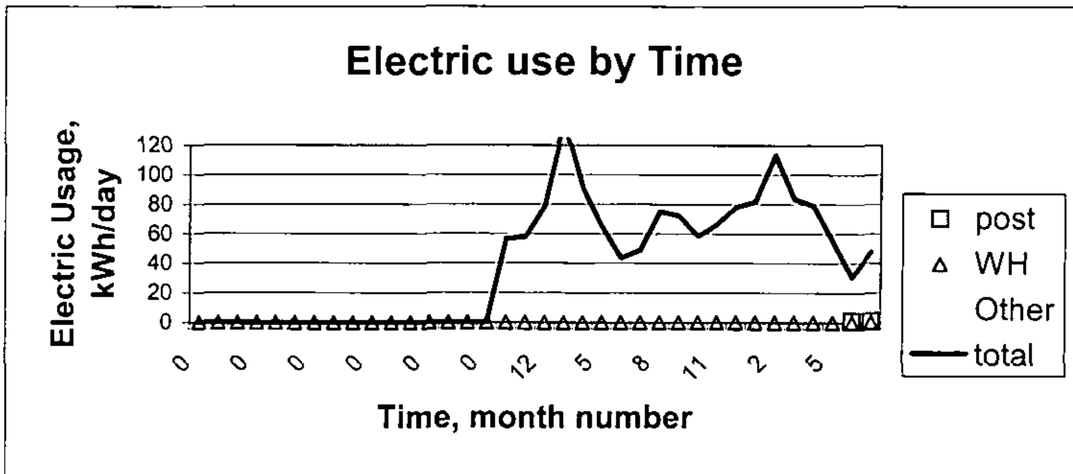
Name	ROBERT STREHLAU			0 months post	NA	pre kwh/d
Account	501509172513			36 months total	NA	post kwh/d
Date retro	06/28/00	latest bill	06/21/00	0 months WH	NA	sav kwh/d

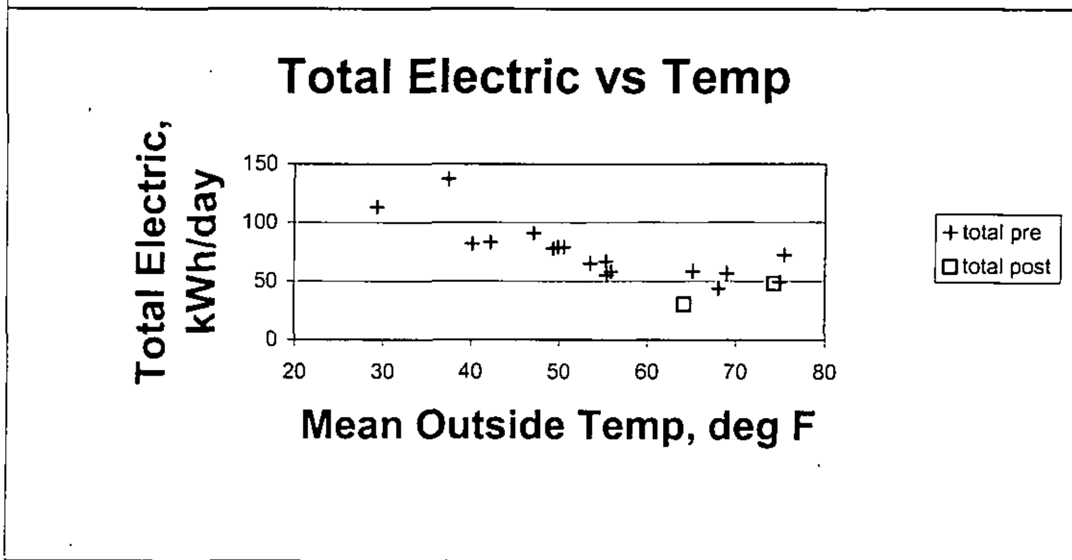


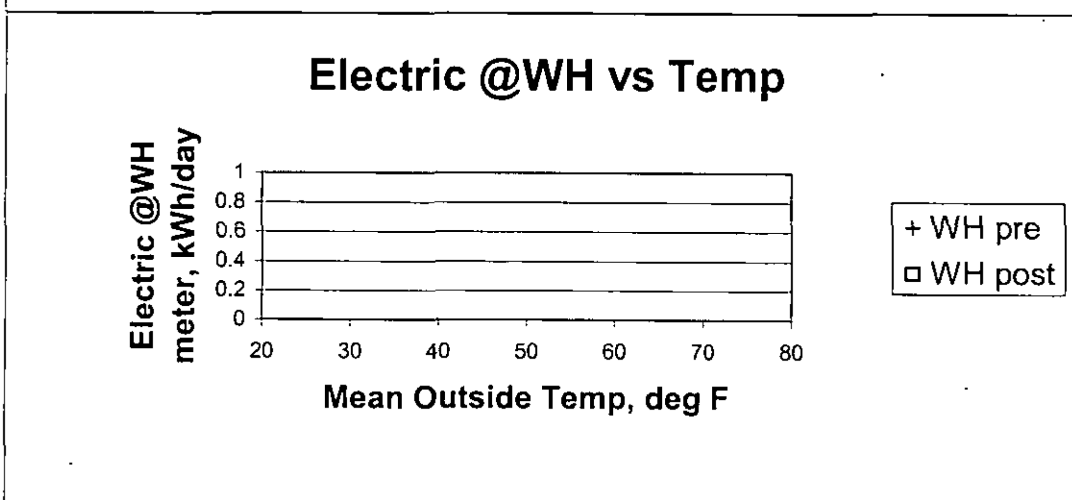




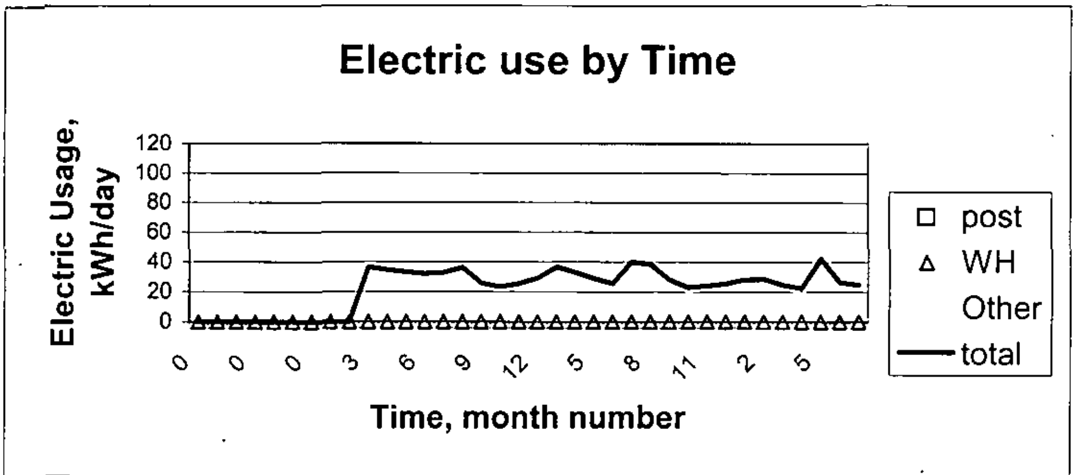
Name	PHILIP L WARMUTH			2 months post	NA	pre kwh/d
Account	350540379533			20 months total	NA	post kwh/d
Date retro	06/06/00	latest bill	07/07/00	0 months WH	NA	sav kwh/d

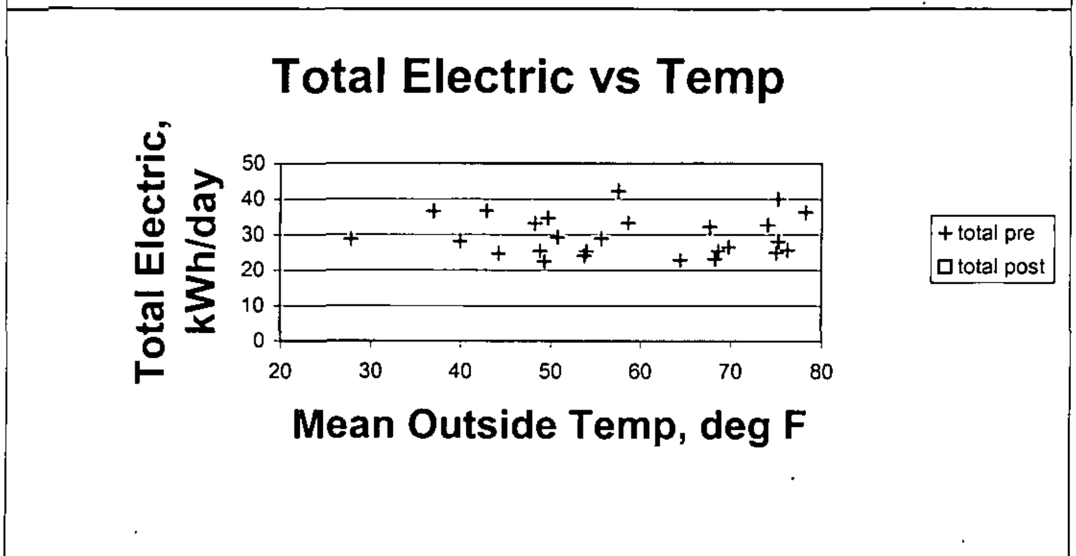


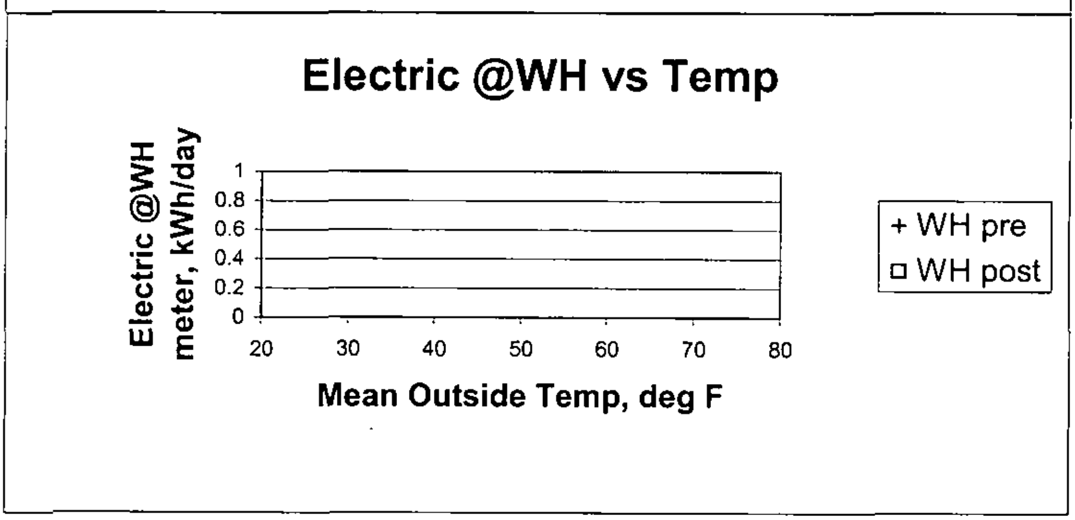




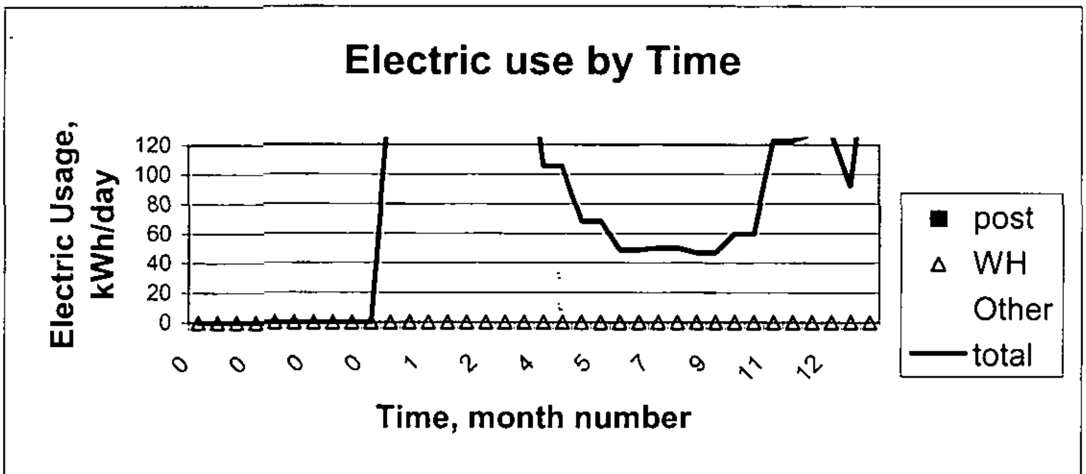
Name	MRS JACQUILYN WILLIAMS		0 months post	NA	pre kwh/d
Account	260715367215		27 months total	NA	post kwh/d
Date retro	09/07/00 latest bill	08/09/00	0 months WH	NA	sav kwh/d

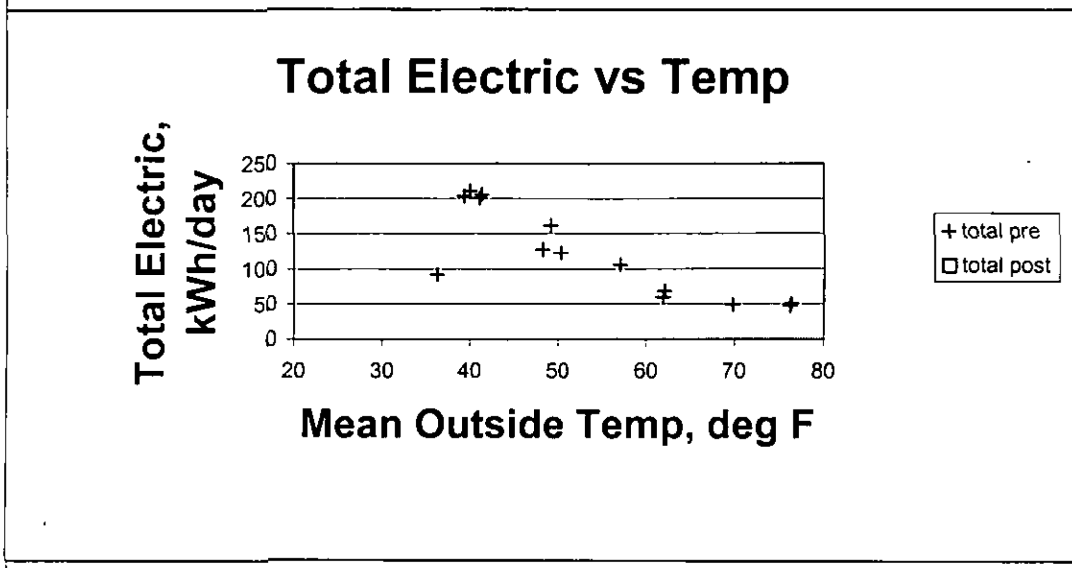


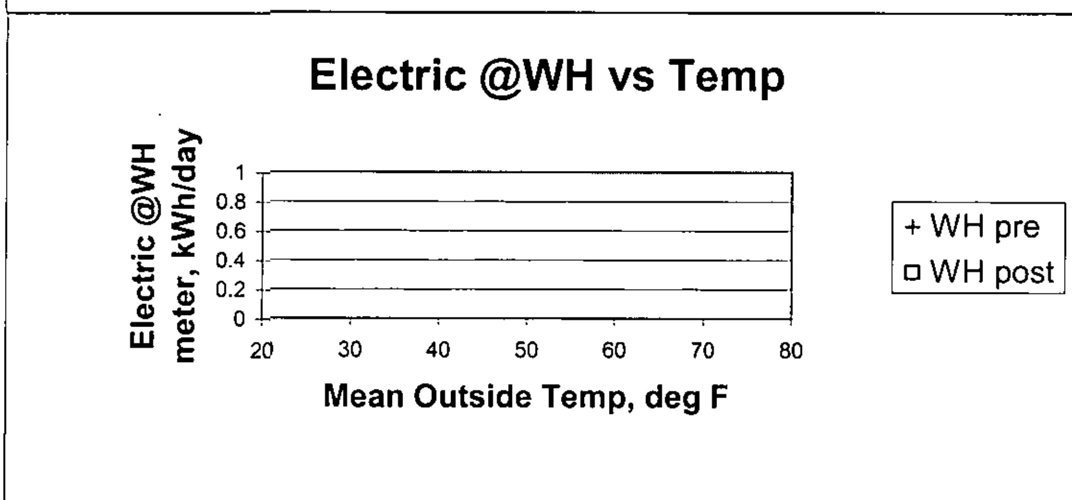




Name	ROBERT RICHARDSON			0 months post	NA	pre kwh/d
Account	251511100264			26 months total	NA	post kwh/d
Date retro	06/02/00	latest bill	03/23/99	0 months WH	NA	sav kwh/d

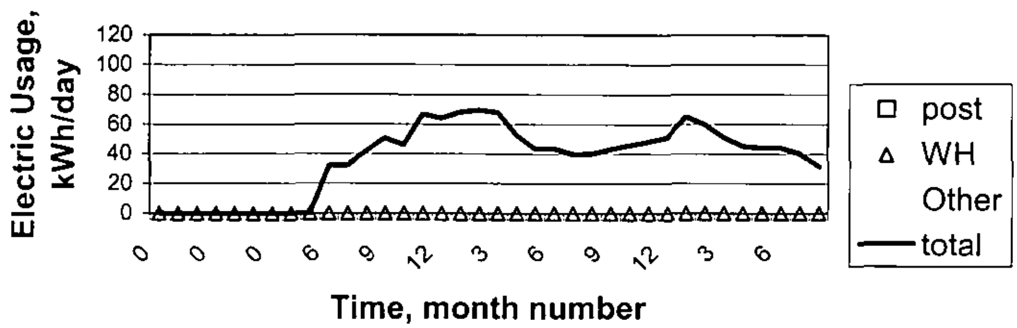




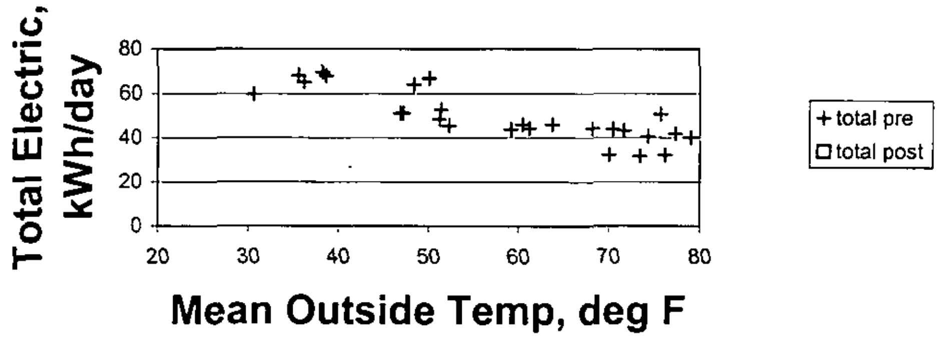


Name	EVELYN PRYER		0 months post	NA	pre kwh/d
Account	261436331241		27 months total	NA	post kwh/d
Date retro	09/07/00 latest bill	08/21/00	0 months WH	NA	sav kwh/d

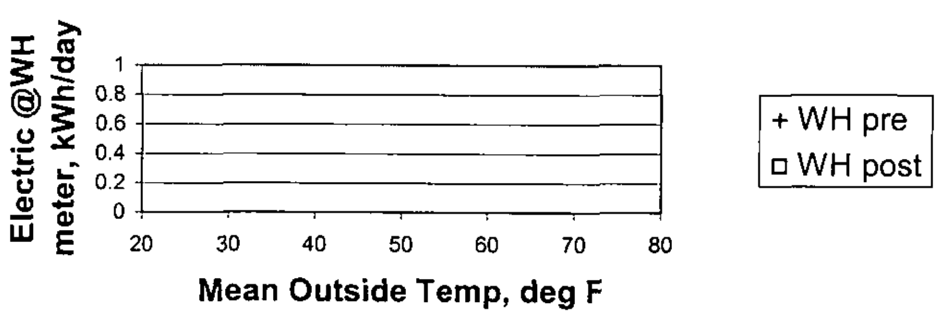
Electric use by Time



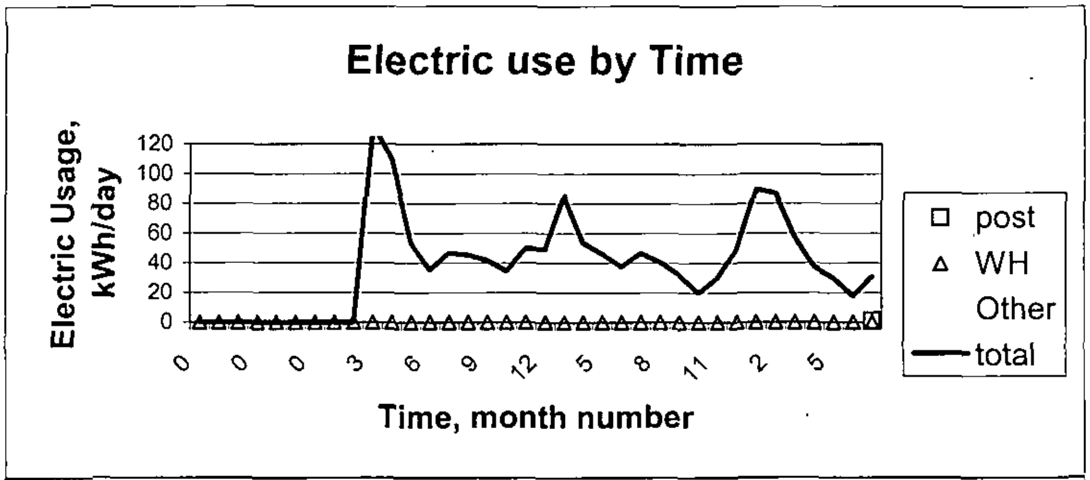
Total Electric vs Temp

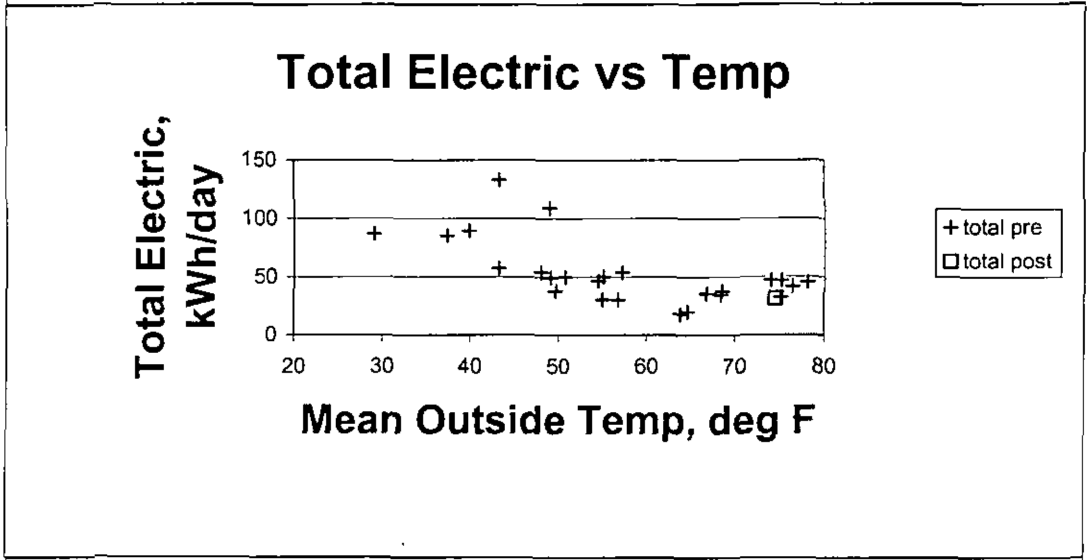


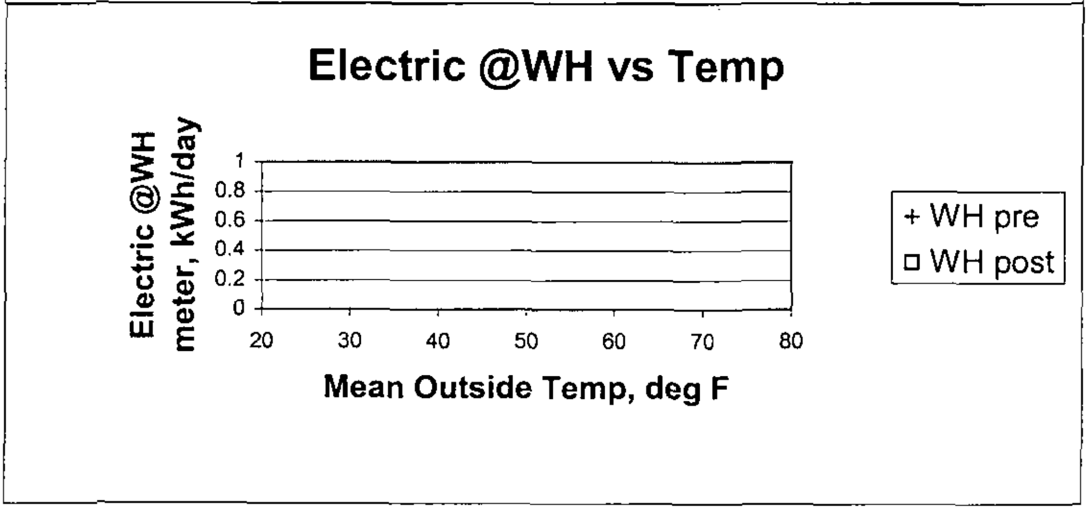
Electric @WH vs Temp



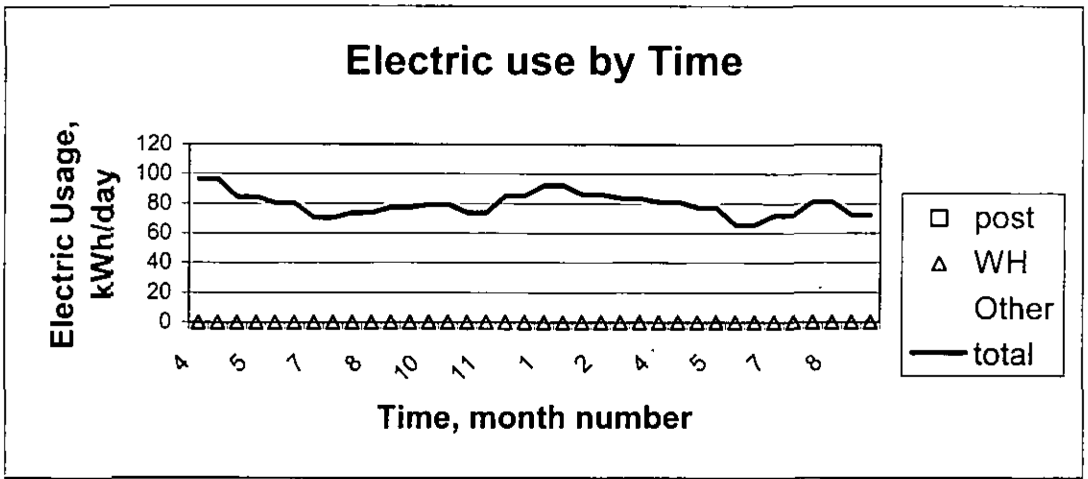
Name	KWAN S KIM			1 months post	NA	pre kwh/d
Account	400606617019			27 months total	NA	post kwh/d
Date retro	06/29/00	latest bill	07/10/00	0 months WH	NA	sav kwh/d

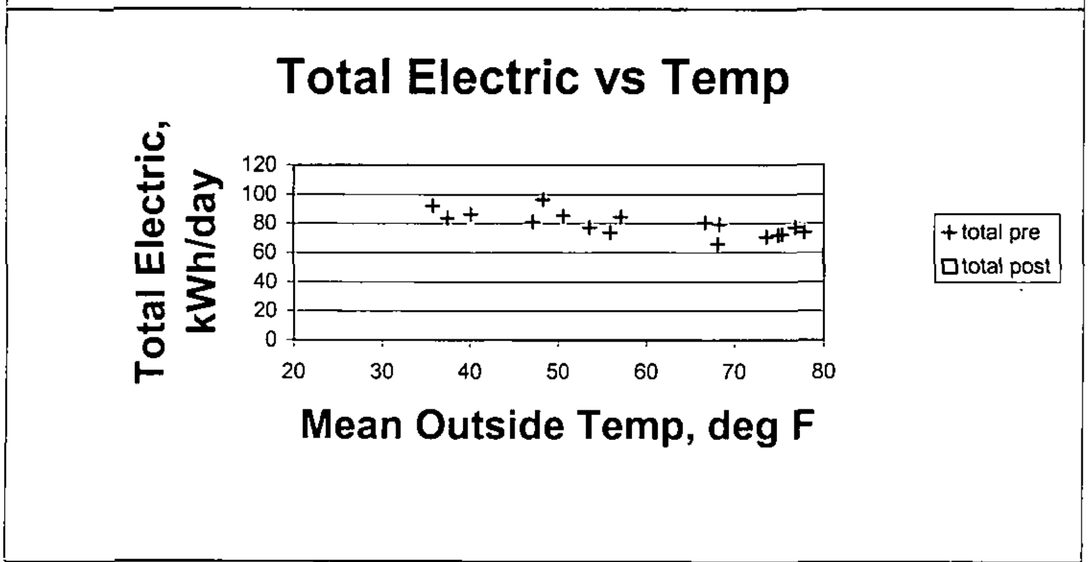


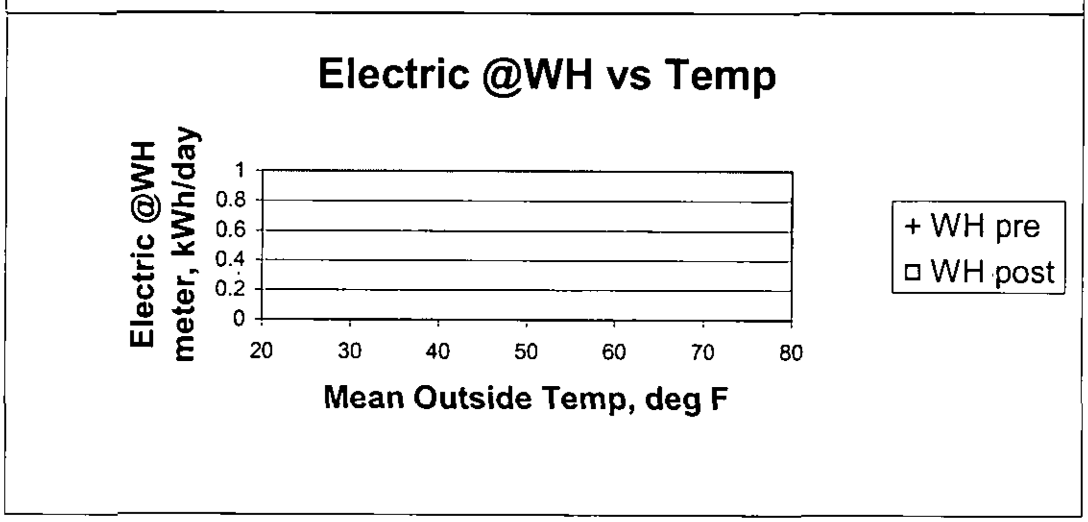




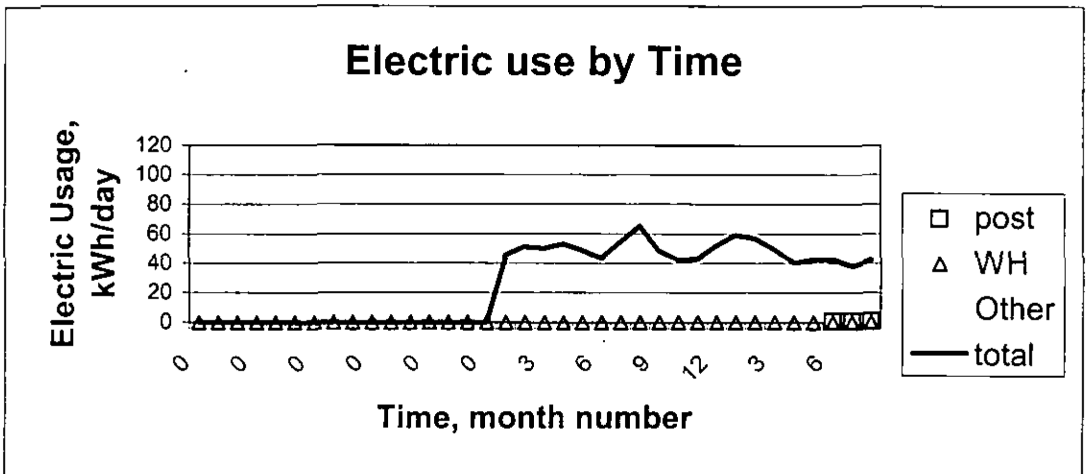
Name	MARY A JEMISON			0 months post	NA	pre kwh/d
Account	350571215523			36 months total	NA	post kwh/d
Date retro	09/01/00	latest bill	09/08/99	0 months WH	NA	sav kwh/d

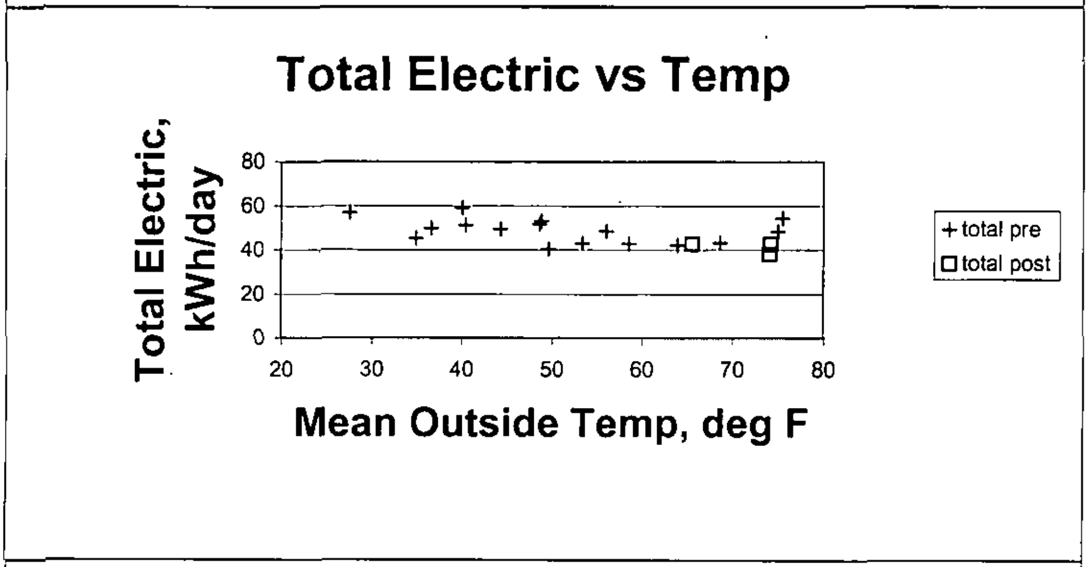


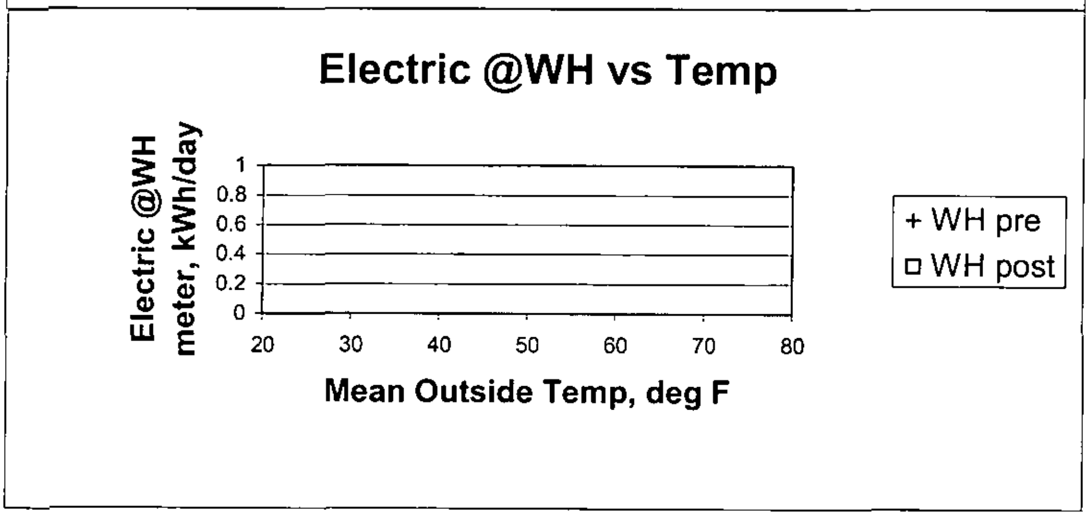




Name	PRISCILLA ATKINSON			3 months post	NA	pre kwh/d
Account	450801002046			20 months total	NA	post kwh/d
Date retro	05/22/00	latest bill	08/11/00	0 months WH	NA	sav kwh/d







Name	ROBIN D HECKLER			2 months post	NA	pre kwh/d
Account	400213259544			36 months total	NA	post kwh/d
Date retro	07/26/00	latest bill	09/01/00	0 months WH	NA	sav kwh/d