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Solar in Federal Buildings Program

Quality Site Seasonal Report
Tucson Job Corps Center, SFBP 1356
November 1984 Through July 1985

Prepared for the U.S. Department of Energy
Division of Solar Heat Technologies
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Energy Technology Engineering Center

Operated for the U.S. Department of Energy
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Quality Site Seasonal Report Tucson Job Corps Center, SFBP 1751 November 1984 Through July 1985

by
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14000 Georgia Avenue
Silver Spring, Maryland 20910

Prepared in Support of
The Solar in Federal Buildings Program
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Preface

In keeping with the national energy policy goal of fostering an adequate supply of energy at a reasonable cost, the U.S. Department of Energy (DOE) supports a variety of programs to promote a balanced and mixed energy resource system. The mission of the DOE Solar Buildings research and Development Program is to support this goal by providing for the development of solar technology alternatives for the buildings sector. It is the goal of the program to establish a proven technology base to allow industry to develop solar products and designs for buildings that are economically competitive and can contribute significantly to building energy supplies nationally. Toward this end, the program sponsors research activities related to increasing the efficiency, reducing the cost, and improving the long-term durability of passive and active solar systems for building water and space heating, cooling, and daylight applications. These activities are conducted in four major areas: (1) Advanced Passive Solar Materials Research, (2) Collector Technology Research, (3) Cooling Systems Research, and (4) Systems Analysis and Applications Research.

Advanced Passive Solar Materials Research -- This activity area includes work on new aperture materials for controlling solar heat gains and for enhancing the use of daylight for building interior lighting. It also encompasses work on low-cost thermal storage materials that have high thermal storage capacity and can be integrated with conventional building elements, and work on materials and methods to transport thermal energy efficiently between any building exterior surface and the building interior by nonmechanical means.

Collector Technology Research -- This activity area encompasses work on advanced low-to medium-temperature (up to 80° C [180° F] useful operating temperature) flat-plate collectors for water and space heating applications, and medium-to high-temperature (up to 204° C [400° F] useful operating temperature) evacuated-tube/concentrating collectors for space heating and cooling applications. The focus is on design innovations using new materials and fabrication techniques.

Cooling Systems Research -- This activity area involves research on high-performance dehumidifiers and chillers that can operate efficiently with the variable thermal outputs and delivery temperatures associated with solar collectors. It also includes work on advanced passive cooling techniques.

Systems Analysis and Applications Research -- This activity area encompasses experimental testing, analysis, and evaluation of solar heating, cooling, and daylighting system integration studies, the development of design and analysis tools, and the establishment of overall cost, performance, and durability targets for various technology or system options.

The Solar in Federal Buildings Program (SFBP) is a Department of Energy Sponsored Program which supports the four major areas listed above. The SFBP involves the design, acquisition, construction and operation of over 700 solar hot water, heating, cooling, passive and process heat systems in new and existing federal buildings. The results of the program are presented in a series of reports covering the design, acceptance testing and performance monitoring of the funded projects.

As part of the SFBP performance monitoring effort, eight federal agency-owned solar heating systems were instrumented and were monitored over several month periods. The projects were chosen based on (1) good agency cooperation, (2) typical system configuration, (3) variety in project function, collector type and geographic location and (4) good design and construction. One of the projects monitored was the Tucson Job Corps Center (Project No. 1356) located in Tucson, Arizona. This 1764ft^2 flat plate solar system is used to heat domestic hot water for the dormitory which houses two hundred students. This report, in support of the system analysis and applications research area, presents the performance results of the Tucson Job Corps Center project. The report includes a system description and a description of the monitoring approach, predicted system performance, monitored system and subsystem performance, lessons learned, as well as recommendations for improving performance at the site.

This work was funded and administered through the DOE, San Francisco Operations Office in conjunction with the DOE, Headquarters Office. The Energy Technology Engineering Center (ETEC) was the program manager. The author would like to thank the DOE and ETEC for their guidance as well as several reviewers for their constructive comments. Special thanks go to Dr. Frederick Morse, Robert Hassett, Wayne Bryan, Oscar Hillig, William Marlatt, Paul Pekrul, Tak Nakae, Keith Balkwill, Arthur Miller, Dr. John Duffie, Dr. George Lof, Richard Rittelmann, and Andrew Parker.

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SUMMARY/ABSTRACT

The active solar Domestic Hot Water (DHW) system at the Tucson Job Corps Center was designed and constructed as part of the Solar in Federal Buildings Program (SFBP). This retrofitted system is one of eight of the systems in the SFBP selected for quality monitoring. The purpose of this monitoring effort is to document the performance of quality state-of-the-art solar systems in large Federal buildings. The systems are unique prototypes. Design errors and system faults discovered during the monitoring period could not always be corrected. Therefore, the aggregated overall performance is often considerably below what might be expected had similar systems been constructed consecutively with each repetition incorporating corrections and improvements.

The solar collector system is installed on a two story dormitory at the Job Corps Center. The solar system preheats hot water for about two hundred students. The solar system provided about 50% of the energy needed for water heating in the winter and nearly 100% of the water heating needs in the summer. There are about 70,000 gallons of water used per month.

There are seventy-nine L.O.F. panels or 1,659 square feet of collectors (1764 square feet before freeze damage occurred) mounted in two rows on the south facing roof. Collected solar energy is stored in a 2,200-gallon storage tank. The control system is by Johnson Controls. City water is piped directly to the storage tank and is circulated in the collectors. Freeze protection is provided by recirculation of storage water. There is an auxiliary gas fired boiler and 750 gallon DHW storage tank to provide backup for the solar system.

Highlights of the performance monitoring from the solar collection system at the Tucson Job Corps Center during the November 1984 through July 1985 monitoring period are:

- Due to freeze damage, the system was available only 82% of the period from November 1984 through July 1985.

- In comparison to a similar NSDN solar system monitored in the Solar Heating and Cooling Demonstration Program, Tucson Job Corps Center solar system performed better, delivering 544 BTU/ft^2-day to the load vs 450 BTU/ft^2-day for the Honolulu Ramada Inn.

- Fossil fuel savings were 322 million BTU over the seven month monitoring period, at a cost in electrical operating energy of 5.87 million BTU (1,719 kWh). At costs of $6.32/million BTU for natural gas and $19.92/million BTU for electricity, this equates to a fossil fuel savings of $2,035.00 and an operating cost of $116.00. The F-Chart extrapolated annual fossil fuel savings are $3834.00 at estimated electrical operating costs of $220.00 for a net annual savings of $3614.00.

- A cost study conducted for the Tucson site indicated that the cost to build a similar commercial installation would be $68,658 in 1985 dollars. Based on this, the cost per square foot of gross collector array (original collector area) for this type of installation would be $38.62. Dividing the normalized installation cost by the annual solar energy delivered by this system in good operational condition yields a cost of $189/million BTU.

- The DHW load (285 million BTU over the seven month monitoring period) was only 50% of the design estimate. There were 127 million BTU of gas used to meet this load. An average of 70,450 gallons of hot water per month was used by the students. This equates to 12 gallons per student per day.

- The total solar energy delivered to the load over the monitoring period was 193 million BTU. This was 92% of that predicted by F-Chart. The percentage of incident solar energy delivered to the loads was 28%. The F-Chart predicted annual solar energy used was 346 million BTU and the extrapolated F-Chart annual solar energy used was 364 million BTU..

- The fraction of the load actually supplied by the solar energy system was 68% as compared to the F-Chart prediction of 74%. The F-Chart annual extrapolated solar fraction was 81% compared to a predicted annual F-Chart solar fraction of 77%.

- The solar system efficiency, defined as the solar energy delivered to storage minus the solar parasitics divided by the total insolation, was 35%. The solar conversion efficiency, defined as the solar energy delivered to the load minus the solar parasitics divided by the total insolation, was 27%. The solar energy delivered to the load divided by the solar parasitics (COP) was 33, where the parasitics over the monitoring period were 1,719 kWh.

- The actual solar insolation in the plane of the collector over the monitoring period was 681 million BTU which is only 89% of the F-chart long-term insolation.

- Collector subsystem performance was awesome for a flat plate array. Collector array efficiency of 36% compared well to the expected value based on ASHRAE collector test results. The collector array output divided by insolation available during solar system operation (i.e., the operating collector array efficiency) was 47%.

- Measured collector-storage transport losses were low - less than 1% of the collected solar energy.

- Storage and distribution losses were high compared to NSDN sites, and compared to theoretical calculations. Seventy-eight percent of the collected energy went to the hot water load. The losses from the 2200 gal storage tank amounted to 52.4 million BTU for the seven month monitoring period. The effective R-value for the storage tank was 1.3 vs 25 as given in the construction specification. The high loss rate is partly because the bottom of the tank inside of the skirt is uninsulated and this area under the tank is open to the ambient air. The average storage tank temperature was 124°F.

- The solar control system suffered a failure in November which caused five collector panels to freeze. The backup freeze protection system was inadvertently disabled. The control failure reduced collector performance in November and January. Subsequent control problems due to lack of operator experience caused some loss of performance in March, June and July. The five damaged panels were bypassed.

- Even with the collector control problems, the system worked well and the total amount of energy rejection was small. The ratio of operational incident energy to total incident energy was 77%.

- The measured collector flowrate was 54 gpm compared to the design flowrate of 42 gpm.

Lessons learned from the Tucson solar system are:

- Operators should receive thorough training. Solar system operators should receive thorough training and documentation in the operation and maintenance of the solar system. The lack of training in operation of the control subsystem and the lack of documentation for the control subsystem resulted in many days of continuous collector pump operation.

- Storage tank stratification improved performance. Storage tank stratification reduced storage losses at Tucson because 71% of storage losses occurred from the uninsulated tankhead.

- Integration of the collectors into the roof improves system performance by reducing losses from the collector panels.

- Storage tank losses can greatly reduce system performance. Care must be taken to fully insulate the entire surface of the tank as well as the tank supports. Thermosiphoning may be prevented in some cases by adding spring tensioned check valves.

- If city water is passed through the system, adequate corrosion protection must be provided for all of the components in the system.

- The system must be provided with an alarm system which alerts the operator when there is a failure and adequately identifies each type of failure.

- The dip tube configuration with a tee and 45° elbow nozzle at each end of the tee was effective in reducing streaming through the storage tank as evidenced by the uniform temperatures throughout the tank when the collector pump was running.

- Measurement of insolation at this site and two other solar sites in Arizona showed insolation levels are below long term values. This points to an important part of the design process for large solar systems which is often overlooked. In order to properly design a solar system, the designer must determine what the solar resource is for the site micro-climate.

- Use of redundant collector pumps is questionable. The use of two collector pumps made it necessary to have a more complex control system and increased the chance for improper system operation.

- Even in mild environments like Tucson, backup freeze protection is required. The use of recirculation of storage fluids for freeze protection was not failsafe. The original strategy for a flush through of city water as a second freeze protection measure was not reliable due to corrosion on the drain out valve. A drainback system would be more reliable.

- In order for the F-Chart model to be successfully used to describe system losses from the DHW system, the auxiliary UA value had to be increased to 180 and the environment temperature adjusted so that the F-Chart generated loads would more nearly match the measured loads.

- An independent TRNSYS simulation of the Tucson collector system indicates that a 4% gain in solar energy used is possible by changing the control to a 5°F on and 1°F off setpoint. (Reference 19).

B. LOAD/AUXILIARY

- Load side recirculation may not be required in some DHW systems. The DHW loadside pump was not needed since there were no particular complaints before the pump was repaired in April.

- Knowledge of load size and profile can improve system design. A better load study could be used to improve system sizing, summer operational strategies and F-Chart predictions.

- Where practical, a change in usage patterns can improve system performance. (Use solar energy as soon after it is collected as possible.) Educating the solar energy consumer to change DHW usage patterns could improve solar energy utilization at this site by 3%.

- During the summer months, DHW systems in climates like that at Tucson may not require any auxiliary energy. Although the auxiliary system was shut off in late June, the system operator probably could have shut the auxiliary off in May.

QUALITY SITE SEASONAL REPORT

TUCSON JOB CORPS CENTER, SFBP 1356
DECEMBER 1984 THROUGH JULY 1985

by T. L. Logee

Section I

OVERVIEW

A. INTRODUCTION

The Solar in Federal Buildings Program (SFBP) is a multi-year legislated DOE program designed to stimulate the growth and improve the efficiency of the solar industry by providing funds to Federal agencies for the design, acquisition, construction, and installation of commercially applicable solar hot water, heating, cooling and process heat systems in new and existing Federal buildings. The program began with the publication of the Final Rulemaking in the October 19, 1979 Federal Register (Volume 44, No. 204) and has progressed through planning, site selection, construction, acceptance testing and monitoring. The Energy Technology Engineering Center (ETEC) is the technical manager of this program for DOE. This report presents the seasonal monitoring final report for the Tucson Job Corps Center site as monitored by Vitro Corporation using National Solar Data Network (NSDN) techniques.

B. PURPOSE

The performance monitoring activity provides the basis for acquiring and evaluating quality performance monitoring data from selected SFBP sites. Quality near-real-time data was acquired from eight selected SFBP sites that were fitted with National Solar Data Network (NSDN) instrumentation. This high quality data from a few carefully chosen representative sites, as opposed to lower quality data from the total population of SFBP sites, provides the best basis for meeting the program objectives.

C. QUALITY SITE PROGRAM OBJECTIVES

The objectives of the monitoring and reporting phase of the program are as follows:

a) Demonstrate that a well-controlled active solar program (SFBP) will result in more efficient systems which more closely achieve predicted performance than had been experienced with previous programs.
b) Analyze and document the differences between selected SFBP sites and similar NSDN sites built earlier and previously monitored to verify improvement in efficiency and provide a basis for industry to improve solar systems.
c) Provide quality data from selected SFBP sites to aid the Department of Energy R&D effort for improving solar systems' performance and cost effectiveness.

d) Document lessons learned for use by Federal agencies, industry and the private sector.

e) Compare subsystem performance conditions for collector, transport, storage, load, and control subsystems.

f) Determine practical limits of solar heating and cooling technology.

D. OVERVIEW OF MONITORING EFFORTS

The Vitro portion of the monitoring program for the Solar in Federal Buildings Program (SFBP) sites began in the spring of 1984 when ETEC sent documentation on the eight selected SFBP solar systems to the Vitro Corporation. This documentation was used to determine the system parameters to be measured and to select instrumentation. In April 1984, the instrumentation plans for the selected systems were sent to ETEC for review. Instrumentation for the Tucson solar energy system, was shipped in the summer of 1984, and installed by contractors in the early fall.

After the installation of the sensors was completed, the sensors and data system were checked out by the Vitro Corporation to ensure that the instruments were reading properly. Data from four sites was being transmitted back to the Vitro Corporation for analysis in October 1984 and by January 1985, data was being received from six solar sites. Data collection at the seventh site was started in February 1985 and at the eighth site in July 1985. The data was automatically collected over the telephone network on command from the System 7 data collection computer located at the Vitro offices in Silver Spring, Maryland. The data was processed in an IBM 3033 computer at the Vitro Corporation. This processing includes error checking, performance evaluation, and data base maintenance.

The Tucson Job Corps Center solar system was monitored for nine months. Monthly reports for the monitoring period were written for each month except December when the solar energy system was down due to freeze damage and February when excessive data was lost due to data logger problems. Annual performance of the system was determined using measured system operational and performance parameters to obtain an F-Chart extrapolation for the missing months.

Section II

SYSTEM DESCRIPTION

A. SITE AND CLIMATOLOGICAL DATA

The Tucson Job Corps Center is located on South Campbell Avenue in Tucson, Arizona. The latitude is 32.3 degrees north and the longitude is 111.1 degrees west. It is at an elevation of 2,584 feet. Long term climatological data from the Tucson National Weather Service Station is used in this report.

Temperatures at Tucson average 67.8°F for the year ranging from a low of 50.9°F in January to a high of 86.3°F in July. There is an average of 1752 heating degree-days and 2,814 cooling degree-days. Tucon's maximum temperatures are usually above 90°F from May through September, with an average of 41 days exceeding 100°F. Relative humidity is low, so these temperatures are not as uncomfortable as they might seem. Tucson is in the area of the country which receives more sunshine than any other section of the United States, averaging 86% of possible sunshine. Expected sunshine averages 1,873 BTU/ft^2-day on the horizontal and ranges from 995 BTU/ft^2-day in December to 2,728 BTU/ft^2-day in June.

B. SOLAR SYSTEM

This flat plate solar collector system is installed in a two story dormitory which houses two hundred students. The solar system schematic is shown in Figure 1. City water is preheated in the solar storage tank before passing to the DHW tank where the preheated water is heated to the final delivery temperature. City water is also the heat transfer fluid used in the solar collectors. The solar system was constructed by Job Corps Trainees as part of a Solar Technical Training Program.

1. Collector Loop. The collector panels are Solar Energy Systems "Sun Panel" Model 121N manufactured by Libby Owens Ford. These collectors have a net area of 19.26 ft^2 and a gross area of 21 ft^2. The collectors are single glazed, with a selective black chrome coating on the copper absorber plates. There are eighty four collectors mounted on the south-facing roof which is sloped at a 30° angle. The collectors are mounted flush to the roof (see Figure 2). There are 1,764 square feet (gross area) of collectors plumbed in six arrays of fourteen collectors each. (The gross collector area was reduced to 1659 square feet after freeze damage to five collector panels.) The collectors are arranged with two rows of seven collectors piped in a parallel series sequence. The discharge of the first row of seven collectors is piped in a series fashion to the inlet of the second row of seven parallel collectors (See Figure 3). Flow balancing valves are plumbed into each subarray supply pipe. The American Society of Heating, Refrigeration and Air Conditioning Engineer (ASHRAE) test (Reference 1) results from a test conducted by the Solar Energy Research Institute (SERI) (Reference 2) indicate an $F_R(\tau\alpha)$ of .66 and a loss coefficient (F_RU_L) of 0.69 BTU/ft^2-°F-hr. The test flow rate was 0.57 gpm, slightly higher than the design flowrate of 0.5 gpm. Make up water is provided automatically since the water to be heated flows directly through the collector panels.

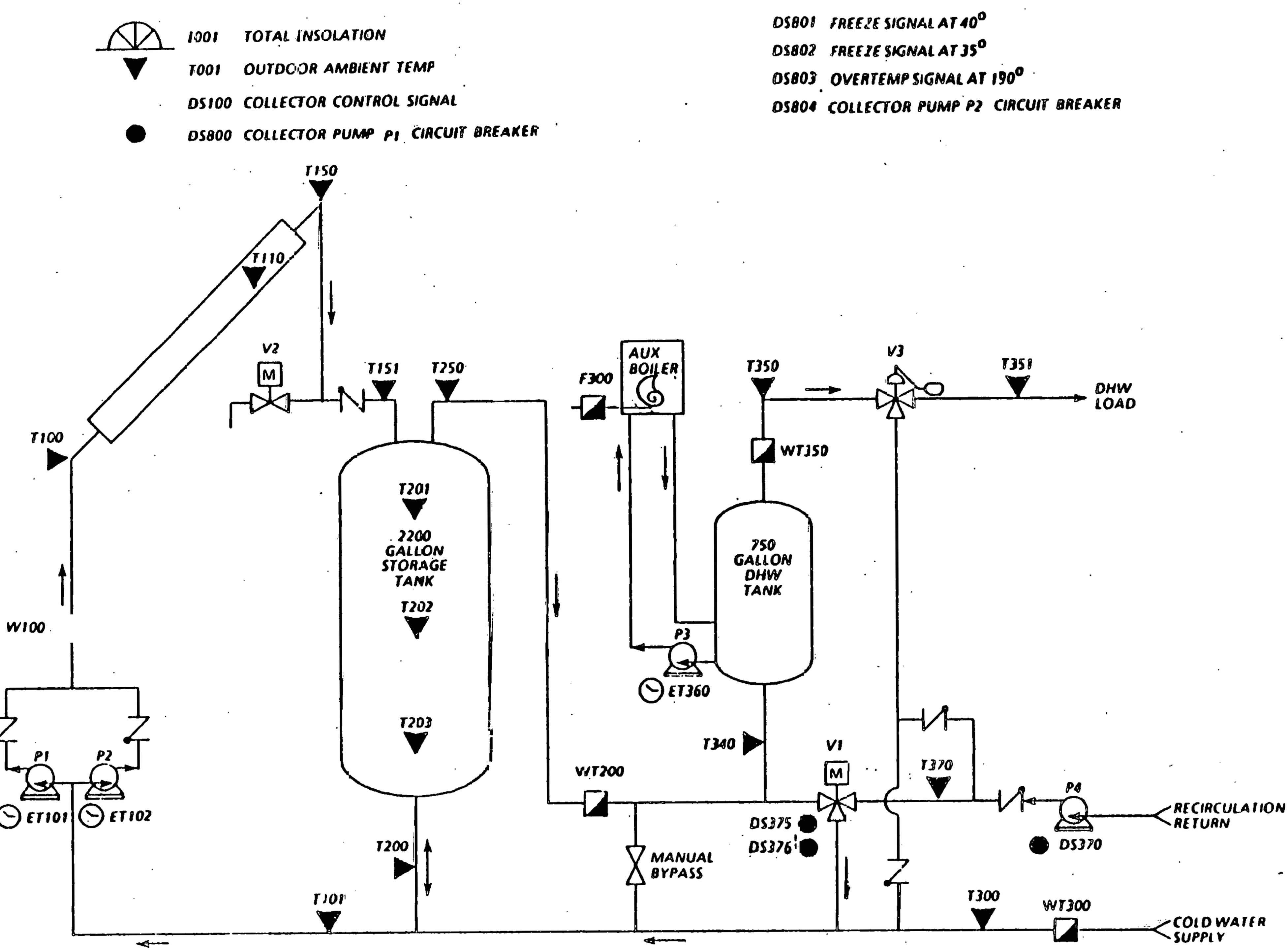


Figure 1. Solar Energy System Schematic

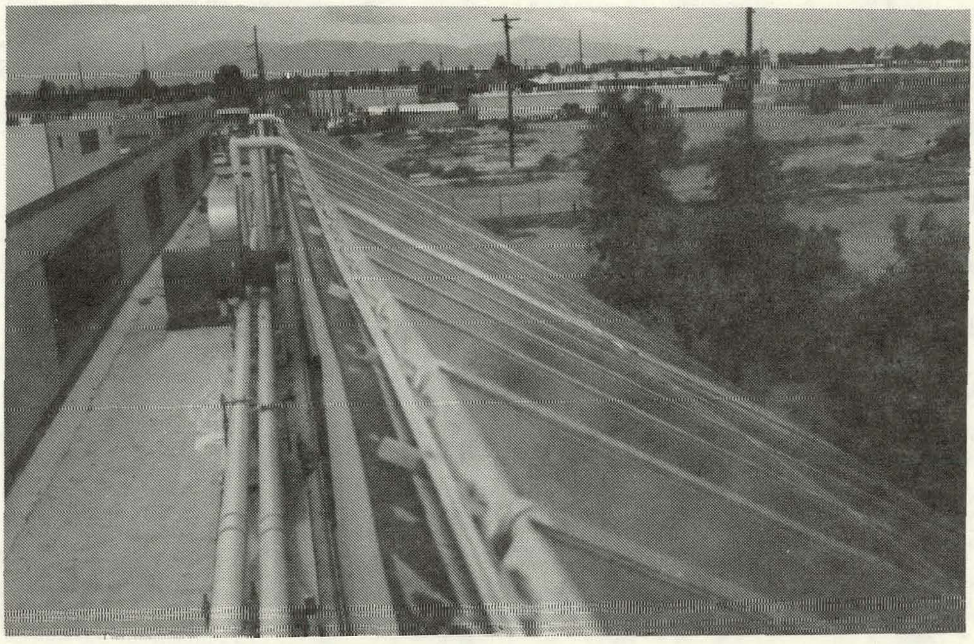


Figure 2. Collector Array
Tucson Job Corps Center

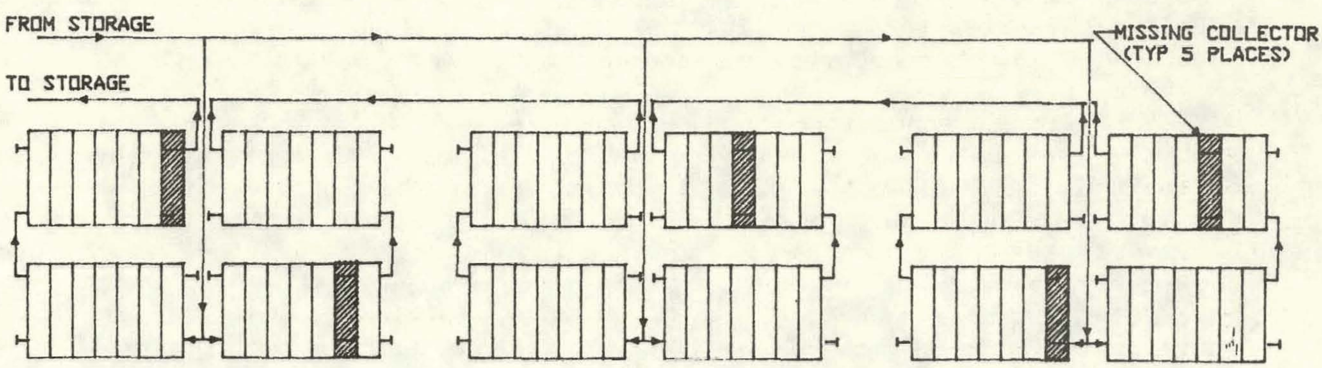


Figure 3. Collector Array Schematic
Tucson Job Corps Center

2. Control System. The control system is provided by a Johnson Controls differential temperature controller in conjunction with temperature sensors and thermostats, a photocell and flow switch. The differential temperature controller is set to turn on the collector pumps at a temperature difference of 20°F between the collector manifold and the bottom of the storage tank, and to turn off the pump when the temperature difference drops below 5°F. The freeze protection mode circulates the storage water through the collectors when the collector plate temperature drops below 40°F. This freeze protection mode is actuated by snap action freeze protection thermostats in each subarray. Backup freeze protection is provided by flushing the collectors with city water. This mode was disabled by site personnel prior to the start of the monitoring period. A photocell sounds an alarm if nighttime operation of the collector pump occurs unless a freezing condition is imminent. The collector pump is shutdown if the storage tank temperature exceeds 190°F. Any pressure buildup is bled off through the pressure relief valve. A collector pump failure is detected as a low flow condition. The "failed" pump is switched out and the "spare" pump is switched on. When pump failure is detected, the "spare" pump runs 24 hours per day. Pump failure results in an audible alarm (silenced by the operator) and a lighted pump failure indicator.

There is a three way valve (valve V-1 on Figure 1) which controls the routing of the DHW recirculation return water. A sensor in the storage tank controls this valve. If the storage tank is warmer than 120°F, DHW recirculation return water flows through the storage tank. If the storage tank is cooler than 120°F, DHW recirculation return water flows through the auxiliary tank only.

3. Storage. The storage tank holds 2200 gallons of water. The tank is 6 feet in diameter and 12 feet high. The tank is mounted vertically on a steel ring base. There are four inches of sprayed on foam insulation covering the tank and the outer surface of the steel ring base but no insulation covers the tank head enclosed by the base. There are access holes in the base, so losses from the tank head are quite high. The tank is insulated from the slab by four inches of foamglas. (See Figure 4)

All piping connections to the tank are made with dielectric fittings and the tank is cement lined to prevent corrosion. An interesting feature of the piping is that the solar collector return has a three foot vertical dip tube through the top of the tank. The dip tube is outfitted with a horizontal tee having a 45° elbow nozzle at each end of the tee. This nozzle arrangement was proposed by ETEC to prevent the streaming which they observed in the tank during acceptance testing. Due to improper installation, the effect of the nozzles creates a slow swirling motion in the tank and the tank is well mixed after a few minutes of collector pumping. Other diffuser designs that improve tank stratification, may have improved performance.

The storage tank is set on a 10' x 10' concrete slab beside the dormitory building. A small concrete block building surrounds the storage tank.

Section III

MONITORING APPROACH

This SFBP solar system was instrumented to be analyzed in accordance with the requirements of the National Bureau of Standards NBSIR 76-1137 (Reference 3). Sensors were used to measure the following (see Appendix D for a description of sensors used):

- o Total insolation in the plane of the collector array,
- o Ambient temperature,
- o Collector subsystem flow rate and temperatures,
- o Storage inlet flow rate and temperatures,
- o Storage outlet flow rate and temperatures,
- o Storage temperature,
- o Storage-to-load subsystem flow rate and temperatures, and
- o Auxiliary fuel flow rates.

The flow and instrumentation schematic (Figure 1, Section II) indicates the relative placement of sensors used in measuring the performance of the system. All of the sensors at this site were installed in accordance with the sensor manufacturers specifications. The sensor locations are given in the Approved Instrumentation Plan (Reference 4) and the sensor wiring instructions are detailed in the Installation Kit (Reference 5).

Site data was recorded automatically at prescribed intervals (five minutes and 20 seconds) referred to as scan level samples through this report by the Site Data Acquisition System (SDAS). The recorded data was transmitted at regular intervals to the Communications Processor in the Central Data Processing System (CDPS). The communications link between the SDAS and the CDPS consisted of a voice-grade telephone line and a telephone data coupler. An internal clock in the SDAS transmitted a time reference with each data scan to ensure that the data was time-tagged correctly. Transmitted data was stored temporarily in the Communications Processor and processed by the host computer. The processing included limit checks to ensure that each data sample was reasonable; that is, within the known instrument limits. Site specific equations were formulated and programmed to calculate Primary Performance factors defined in the NBSIR 76-1137 document. The equations used to evaluate data from the Tucson Job Corps system, including the algorithms used to bridge data gaps and to integrate scan level data into hourly and daily values, are described in Appendix B.

The methodology used for data evaluation is the same as that developed for analysis of the National Solar Data Network solar systems (Reference 6). Basically, this involves the calculation of energy gains and losses from each subsystem in accordance with the analytical procedures of NBSIR 76-1137. The values determined by this method were checked by calculating energy balances for each subsystem and for the interfaces between each subsystem. This energy balance approach is represented graphically by the energy flow diagram presented in Section V of this report. The loss arrows on this diagram represent the energy which is unaccounted for including measurement error. Loss values were carefully evaluated to determine if they were reasonable. The energy flow diagram is an invaluable tool. In addition to verifying the accuracy of the measurement data, the energy flow diagram provides a means of identifying abnormal conditions such as unusually high pipe and duct energy losses and malfunctioning valves and dampers.

As a check of the measured energy flows, thermal losses from each subsystem were estimated. The estimates are based on a physical description of the equipment and building structure, and knowledge of the pertinent temperatures. Thermal losses from liquid systems include conductive heat transfer through the fluid container (e.g., storage tank, pipes, and collector). The environment temperature associated with thermal losses is also needed to make conductive and convective heat transfer estimates. The measured building temperature is adequate if the losses occur in the conditioned space, and the external environment (ambient) temperature is adequate if the losses occur in the exterior environment. Losses into an unconditioned space can be difficult to estimate without some knowledge of the space temperature. For this reason temperatures in the unconditioned areas where storage tanks are located were measured.

In general, energy flows were computed with a large number of scan-level samples. Typically, error from instrument noise and sampling of phenomena that were random or close to random were not significant compared to a net instrumentation bias error. Measurements which have bias errors that apply uniformly to measurements used to compute energy flows were corrected for the bias before assessing the expected measurement accuracy on an energy balance. The assessment of the expected measurement accuracy on an energy flow balance considers the net bias error.

All sensors were calibrated and certified by the manufacturer prior to deployment (Reference 7). Calibration factors were factored into the test results at the time of data processing. After completion of testing, the collector subsystem and load sensors were recalibrated by the manufacturer (except the water totalizers which were calibrated by ETEC) (Reference 8). Each reported performance factor has a degree of uncertainty associated with it i.e. an unknown deviation of the measured parameter from the true value of the parameter. The degree of uncertainty associated with each parameter is a function of the uncertainties produced by three basic sources - the sensor, data collection/transmission and computational error.

The main sources of sensor uncertainty include sensor calibration error, uncertainty due to the limited sensitivity/resolution of the sensor, uncertainty due to location of the sensor in the solar system and error due to sensor drift. The first two types of sensor uncertainty are random; the latter two result in a sensor bias. In this study, the sensor manufacturer's specifications have been used to quantify the first two types of uncertainty. Sensor bias due to placement of the sensor was more difficult to quantify. In some cases it was possible to compare sensor measurement in the system and determine the amount of bias. If the bias due to sensor placement could be quantified, the measurement was corrected in the performance software. Drift of the sensors used to make the most critical measurements (insolation, temperature and flow) was determined by conducting pre- and post-calibration of the sensors. Since the rate of sensor drift is not necessarily uniform, the data could not be corrected for this effect. The estimated parameter errors given in the table below include the effects of sensor drift as determined by the pre- and post-calibration.

Data collection/transmission uncertainty are caused by noise generated in the data logger and communication equipment, resolution of the data logger equipment, resolution of the data logger digital system used (1024 counts) and from the sample rate used. The uncertainty due to these factors is random and do not usually exceed one count.

An estimate of the combined effects of sensors and data collection/transmission uncertainty was determined by using the manufacturer's specifications, pre- and post-calibration data and one count of collection/transmission error. The average uncertainty for each type of measured parameter is presented in the table below

Measured Parameter	Estimated Parameter Uncertainty (sensor & non-uniform data acquisition bias)
Insolation	± 2.5% of full scale
Fluid Flow Rate (Impact Fluid Flow Rate type flow meter, meter reading greater than 50% full range)	± 1.4% of full scale
Fluid Volume (Displacement type flow meter)	± 2% of full scale
Elapsed timers	± 7 seconds
Temperature (liquid sensor)	± 0.8°F
Temperature (air sensor) (includes a bias due to sensor placement)	± 1.0°F
Natural Gas Usage	± 4% of full scale

All sensors were within acceptable limits except T150 which has an uncertainty ± 1.1°F. Flow sensor W100 often read slightly above the full scale value but not beyond the resolution or accuracy of the sensor. Expected measurement accuracy is the sum of a bias from the sensor and a bias from the data acquisition system that is not uniform on all sensor channels.

The total expected uncertainty in a measured energy flow is dependent on the combined uncertainties of the parameters which were measured in determining the energy flow and may be calculated using the following equation (from NBSIR 76-1137 Reference 3):

$$\text{Uncertainty in Energy Flow} = \left[\sum_{i=1}^{N} \left(\frac{\partial E}{\partial Xi} \Delta Xi \right)^2 \right]^{\frac{1}{2}}$$

where:

ΔX_i = error in each term of the energy performance equation i.e. the sensitivity of energy flow to measurement,

$\frac{\partial E}{\partial X_i}$ = partial derivative of each term in the particular energy performance equation

N = number of terms

For example, applying the above equation to the measurement of the solar energy collected at Tucson, the uncertainty is ± 16% since the combined uncertainties of an impact flow meter and two temperature sensors are involved.

Section IV

EXPECTED MONITORING PERFORMANCE

A. ACCEPTANCE TEST

The acceptance test was conducted by ETEC personnel on August 25 and 26, 1982. ETEC found the following minor mechanical problems:

a) A leak at an air vent and subsequent insulation damage.

b) Control Sensors T3 and T4 not waterproofed.

The collector efficiency points (Figure 8) were well above the 75% of ASHRAE single panel test curve, fulfilling the acceptance test criteria established in ETEC document SFBP-XT-0015 (Reference 9). The one recommendation to improve performance was to install a flow diffuser onto the storage tank dip tube. The flow diffuser was installed before field monitoring.

ETEC personnel found the collector system to be very efficient and the workmanship to be excellent. The collector efficiency plots from the acceptance test agree quite well with similar plots from this monitoring program.

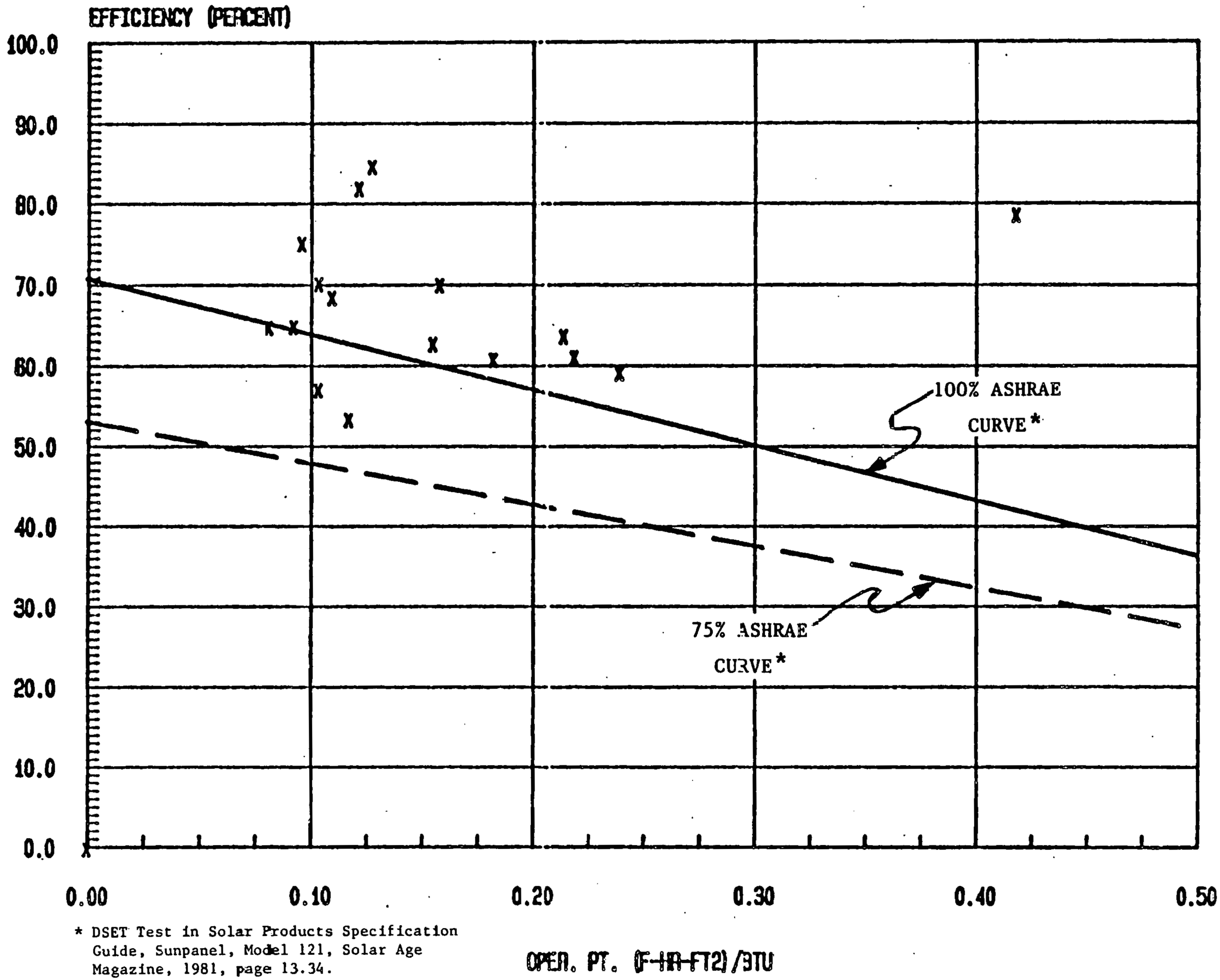
The Acceptance Test Data flow rate was 42.5 gpm versus the monitored flow rate of 54 gpm because the acceptance test was performed before the circuit setters were removed. The close agreement between the collector efficiency curves shows that changes in flow rate have little effect on collector performance.

B. EXPECTED SYSTEM PERFORMANCE

An F-Chart Analysis was run for the Tucson Job Corps System. This analysis used measured flowrates and monthly loads, for the months during the Vitro monitoring period (an average of the measured loads was used for the other months), and the ASHRAE 93-77 test collector efficiency curve from SERI. See Table F-1 (Appendix F) for a detailed list of the input parameters used. The F-Chart analysis predicted a solar fraction of 73% for the seven monitored months and an annual solar fraction of 77% (see Table 1). (See Section V for a comparison of these values with the measured results.)

C. PREDICTED ENERGY SAVINGS

The predicted annual energy savings based on 346 million BTU of solar energy used and an assumed furnace efficiency of 60% (see Reference 3), less 10 million BTU of operating energy, are 577 million BTU.



* DSET Test in Solar Products Specification Guide, Sunpanel, Model 121, Solar Age Magazine, 1981, page 13.34.

Figure 8. Acceptance Test Plot of Collector Array Efficiency
Tucson Job Corps Center

Table 1. F-CHART PREDICTED PERFORMANCE

TUCSON JOB CORPS CENTER

*** WATER STORAGE SYSTEM ***
** FLAT PLATE COLLECTOR **

	SOLAR MMBTU	HEAT MMBTU	DHW MMBTU	AUX MMBTU	F
JAN	84.0	0.0	44.4	17.2	0.61
FEB	93.1	0.0	49.0	16.5	0.66
MAR	99.0	0.0	52.3	18.3	0.65
APR	106.0	0.0	47.2	11.7	0.75
MAY	109.0	0.0	43.3	8.3	0.81
JUN	108.0	0.0	32.9	1.9	0.94
JUL	101.0	0.0	23.4	0.2	0.99
AUG	115.4	0.0	26.2	0.0	1.00
SEP	113.6	0.0	31.1	0.5	0.98
OCT	89.5	0.0	27.6	4.1	0.85
NOV	75.0	0.0	43.5	19.8	0.54
DEC	87.1	0.0	28.3	4.5	0.84
YR	1180.6	0.0	449.1	103.0	0.77

SOLAR is the monthly total solar radiation incident on the collector surface in MMBTU (million BTU).

HEAT is the monthly space heating load (MMBTU).

DHW is the monthly water heating load (MMBTU).

AUX is the monthly total auxiliary energy required to supply the domestic water heating load (MMBTU).

F is the fraction of the water heating load which is supplied by solar energy.

Section V

MONITORING RESULTS

A. THERMAL PERFORMANCE

1. Weather Conditions. Measured and long-term average weather data are shown in Table 2. The long-term average daily incident solar energy per unit area is 2135 BTU/ft^2-day compared to the measured value of 1890 BTU/ft^2-day. The long-term insolation is 245 BTU/ft^2-day or 13% greater than measured insolation. For the reader's interest, the measured insolation at Phoenix, Arizona for seven months in 1981 and 1982 at a tilt of 20° and azimuth of 34° West of South (Reference 10) was also 13% lower than the long-term insolation. In Scottsdale, Arizona for nine months in 1981 and 1982 for a horizontal pyranometer (Reference 11), the measured insolation was 19% below the long-term insolation. Although these three measurements are not enough to conclude that there is less insolation in Arizona in the 80's, it is interesting to note that the measured insolation is consistently below the long-term weather for each month also. The uncertainty in the pyranometer measurement at Tucson is 1.8% (a little better than the expected uncertainty of ± 2.5% for this type of instrument) or 34 BTU/ft^2-day out of 1890 BTU/ft^2-day.

Table 2. WEATHER CONDITIONS

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

MONTH	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/ft^2-day) MEASURED (SE)	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/ft^2-day) LONG-TERM AVERAGE	AMBIENT TEMPERATURE (°F) MEASURED (TA)	AMBIENT TEMPERATURE (°F) LONG-TERM AVERAGE	HEATING DEGREE-DAYS MEASURED (HDD)	HEATING DEGREE-DAYS LONG-TERM AVERAGE	COOLING DEGREE-DAYS MEASURED (CDD)	COOLING DEGREE-DAYS LONG-TERM AVERAGE
NOV	1.406E	1,802E	53E	59	328E	221	8E	26
JAN	1,514E	1,679E	50E	51	445E	442	0E	0
MAR	1,924	2,198	60	58	141E	243	28	12
APR	2,131	2,408	72	66	28	81	240	96
MAY	2,117E	2,426	80E	74	5E	0	446E	272
JUN	2,178E	2,351	87E	82	1E	0	627E	513
JUL	1,958	2,080	89	86	0	0	765	660
TOTAL	-	-	-	-	948E	987	2,114E	1,579
AVERAGE	1,890E	2,135	70E	68	135E	141	302E	226

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to indicate the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% but more than 40% measured data. See Appendix B for bridging methodology used.

The long-term average insolation values are calculated using the RBAR routine (Reference 12) from F-Chart to convert horizontal data to collector plane data, from derived long-term values for Tucson, Arizona, found in Input Data for Solar Systems (Reference 13). Long-term ambient temperature and degree-day data were taken from the same source.

The ambient temperature averaged 70°F versus 68°F long term. Note that the measured monthly average temperature was below long term in November and significantly above long term in April, May and June. There was a roof vent near the ambient sensor which caused an 8°F bias on hot days when the storage room door was open. An estimate of this measurement bias on the uncertainty of the ambient temperature measurement still only causes about a 1% error in the seasonal average temperature. The error in ambient temperature measurements had negligible effect on collector operating point since outlying points which are greater than three standard deviations are filtered out and the few bad points within acceptable limits have no apparent impact on the operating point derived from all of the data points.

The measured heating degree days were 948 compared to 987 for the long term average. The bias on the ambient temperature sensor didn't significantly affect heating degree days. The measured cooling degree days were 2114 compared to 1579 long term average cooling degree days. However, the bias of 8°F on the outdoor ambient sensor caused a greater impact on cooling degree days because this bias occurred more frequently during hot weather. Consequently, the uncertainty in the measured cooling degree days is about 25%.

2. Collector. The Libby Owens Ford Sunpanel collectors of the Tucson Job Corps Center performed at the level of efficiency equivalent to the single panel ASHRAE Test. The monthly and seasonal performance of the collector subsystem is shown in Table 3. The seven month average collector

Table 3. COLLECTION SUBSYSTEM PERFORMANCE

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION (SEA)	COLLECTED SOLAR ENERGY (SECA)	COLLECTION SUBSYSTEM EFFICIENCY (%) (CLEF)	OPERATIONAL INCIDENT ENERGY (SEOP)	COLLECTOR ARRAY OPERATIONAL EFFICIENCY (%) (CLEFOP)	ECSS OPERATING ENERGY (CSOPE)	SOLAR ENERGY TO STORAGE (STEI)	DAYTIME AMBIENT TEMPERATURE (°F) (TDA)
NOV	75E	17.4E	23E	38.7E	45E	0.32E	17.3E	58E
JAN	84E	15.4E	19E	43.9E	35E	1.03E	15.0E	58E
MAR	99	37.1	38	85.1	44	0.92	36.6	71
APR	106	47.3	45	87.0	54	0.59	47.0	83
MAY	109E	47.0E	43E	87.5E	54E	0.61E	46.8E	91E
JUN	108E	42.4E	39E	91.2E	47E	0.84E	42.0E	99E
JUL	101	41.8	41	91.9	45	1.56	41.0	100
TOTAL	681E	248E	-	525E	-	5.87E	246E	-
AVERAGE	97E	35.5E	36E	75E	47E	0.84E	35.1E	80E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% but more than 40% measured data.
See Appendix B for bridging methodology used.

efficiency was 36% and the operational collector efficiency was 47%. The collector efficiency for the months of November and January is low due to the collector freezeup incident on November 26, 1984. The system was repaired by removing the five damaged collector panels on January 9, 1985, thus reducing the collector area to 1,659 ft^2. (See Hardware and Instrumentation Problems, Section V.C.1, for more details). The collector subsystem performed better in April and May due to the sunny weather and lower collector inlet temperatures. Although June was the sunniest month, system loads were smaller, (See Table 5) so collector inlet temperatures were significantly higher and consequently collector efficiency was lower. Also in June and July, solar energy available often exceeded demand so storage tank temperatures and losses were high. The collector system shut off at a storage high temperature of 205° on almost a third of the days in June and July.

There were 681 million BTU of solar energy incident on the collector array and 248 million BTU collected; 525 million BTU of solar energy was incident on the collector array during operation of the collector pump. The average daytime ambient temperature was 80°F.

The collector pump required 5.87 million BTU to pump the collector fluid through the collectors. The 1.03 million BTU of pumping energy used in January was due to continuous operation of the collector pump. (See Hardware and Instrumentation Problems, Section V.C.1, for details). During parts of January and June and most of July, the collector pump also ran continuously. It is estimated that as much as 17% of the collected solar energy was lost at night through the collectors due to the continuous pump operation during these months.

The monthly plots of collector efficiency versus operating point are presented in Figures 9 through 15.

Operating point, (TIN-TA)/I, is the inlet temperature to the collectors minus the outdoor temperature divided by the insolation while the collectors are operating. The plot is for hours during which there was continuous flow through the collector array while there is sunlight. Transient effects related to startup operations often result in higher and/or lower efficiencies than subsequent hours at the same operating point. Therefore points are not used until after an hour of continuous operation has occurred. Outlying points which are greater than three standard deviations from the first order fit of the data are also filtered. The first order curve fit information in the upper left of the plot is valid only for the range of values of (TIN-TA)/I available. This plot is representative of the performance of this particular collector array for the specified month. Note that the measured points cluster around the ASHRAE test line with July being above and November being below. The average of all the regression lines falls nearly on the ASHRAE curve. Points on the right side of the plots in January and July are due to continuous operation of the pump. These represent early morning operating points which normally would have been discarded due to cycling of the pump.

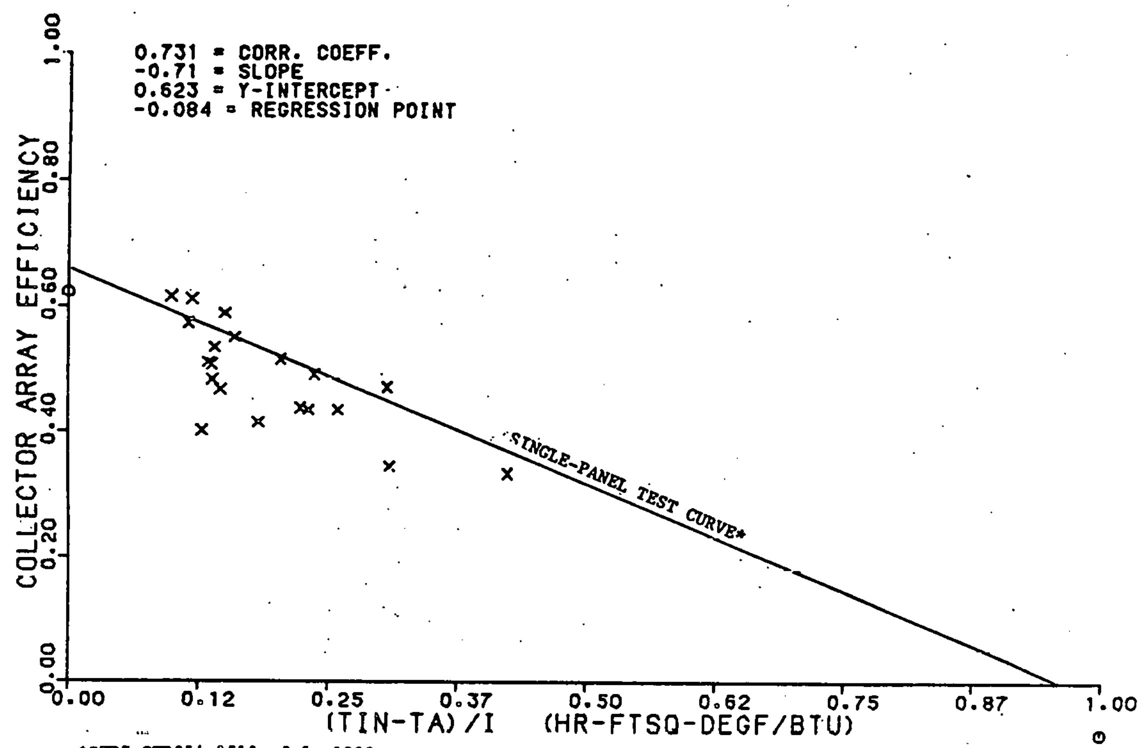
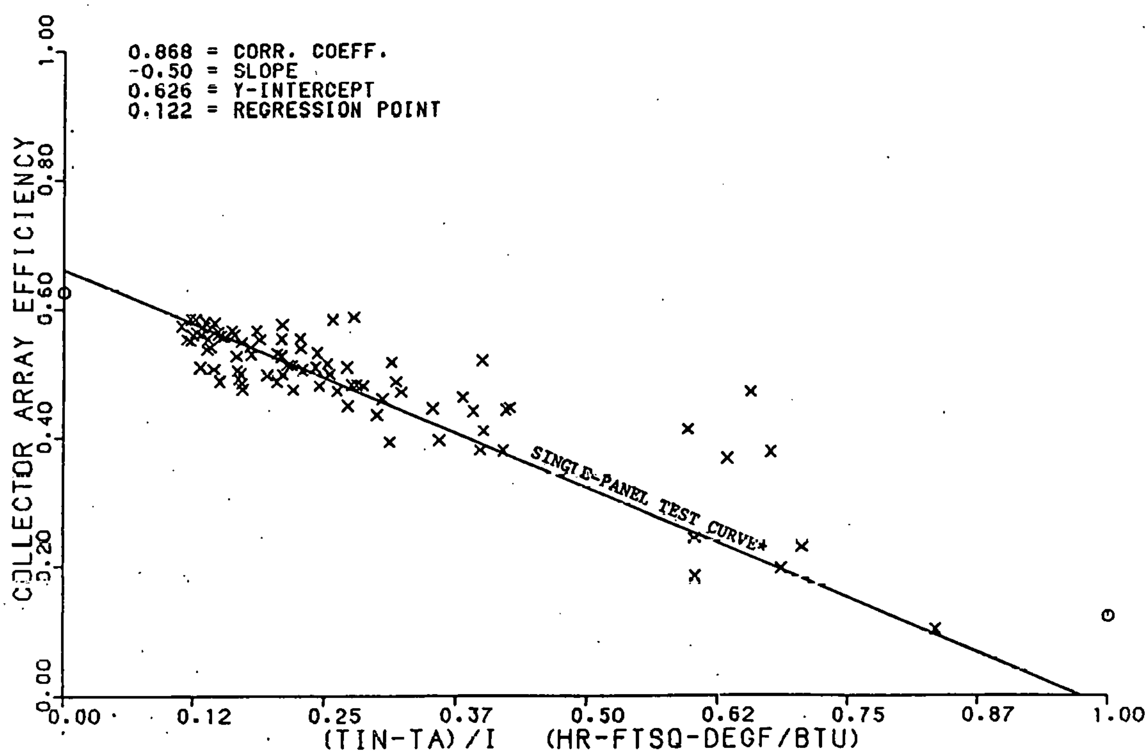
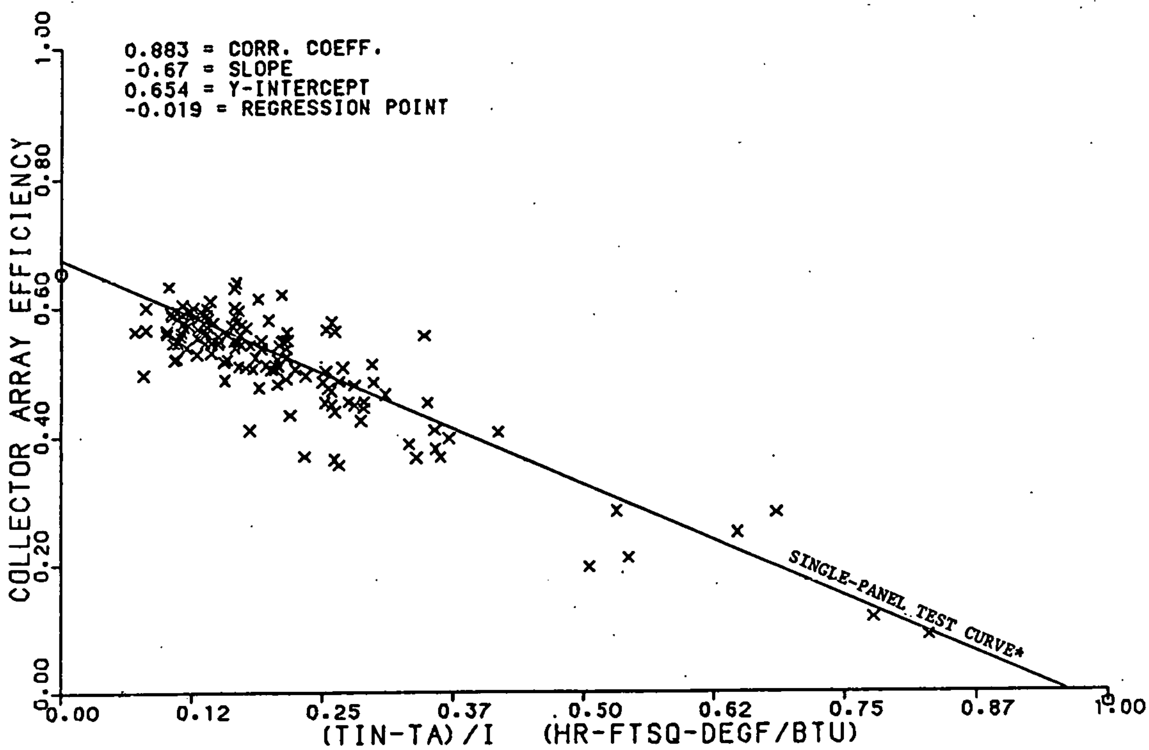


Figure 9. Collector Array Efficiency
Tucson Job Corps Center
November 1984



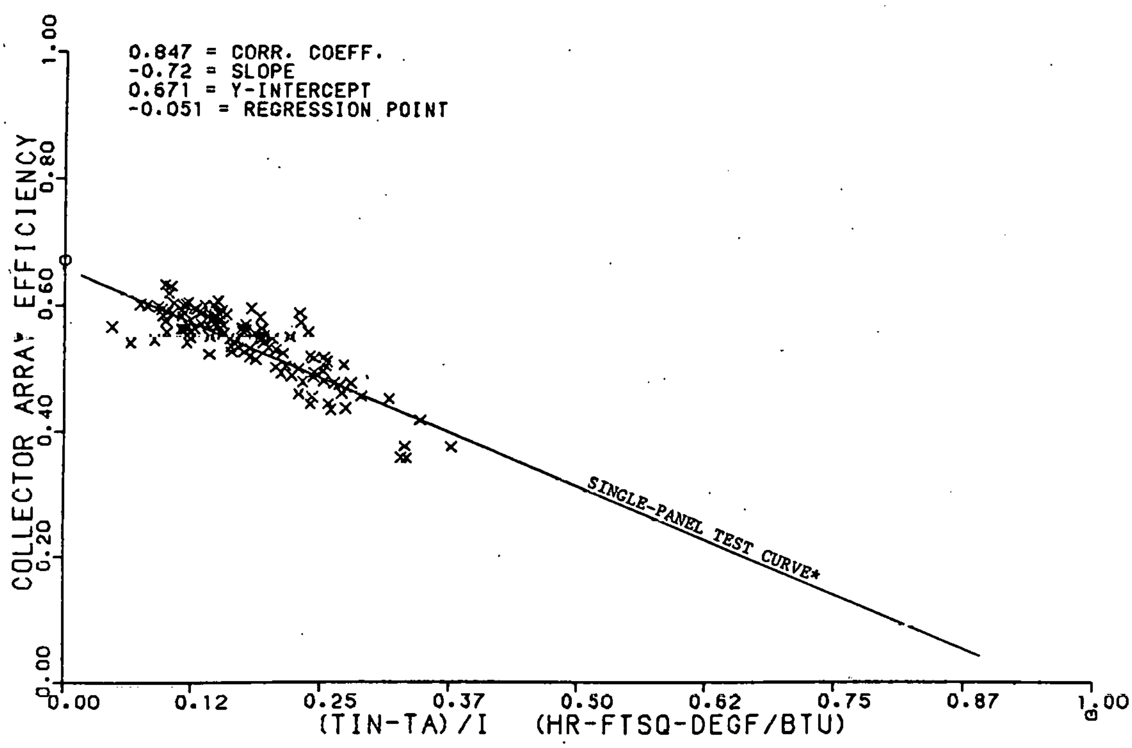
*SERI STR254-1515, July 1983

Figure 10. Collector Array Efficiency
Tucson Job Corps Center
January 1985



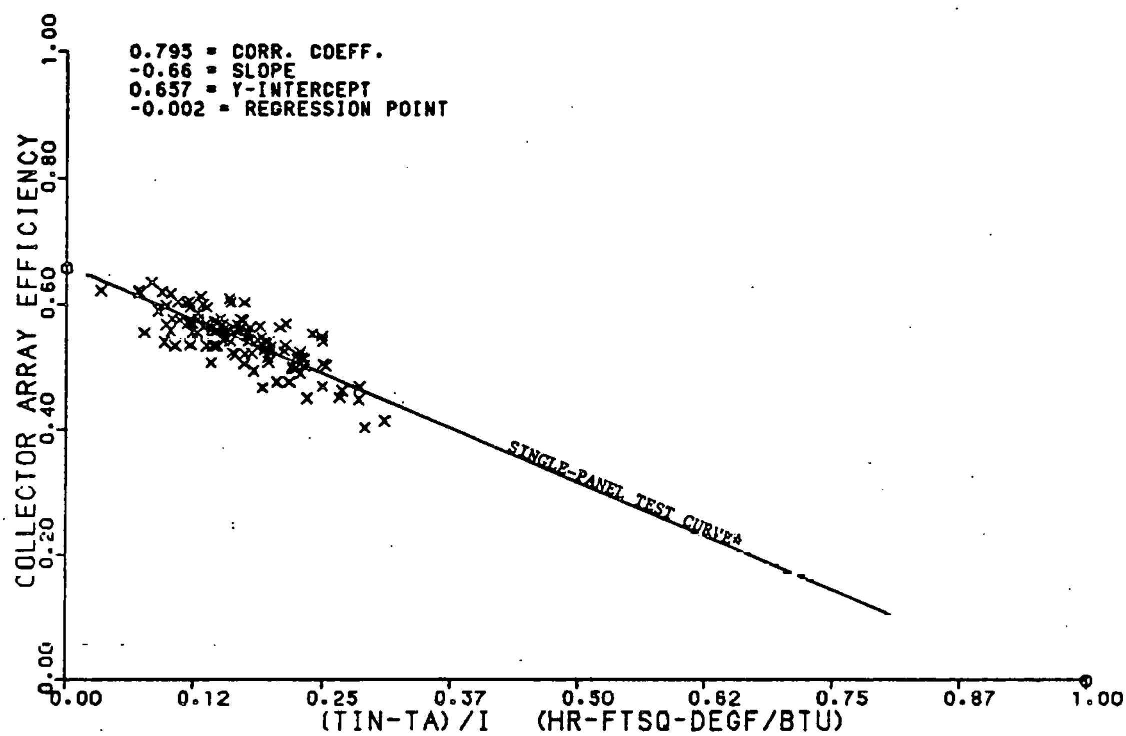
*SERI STR254-1515, July 1983

Figure 11. Collector Array Efficiency
Tucson Job Corps Center
March 1985



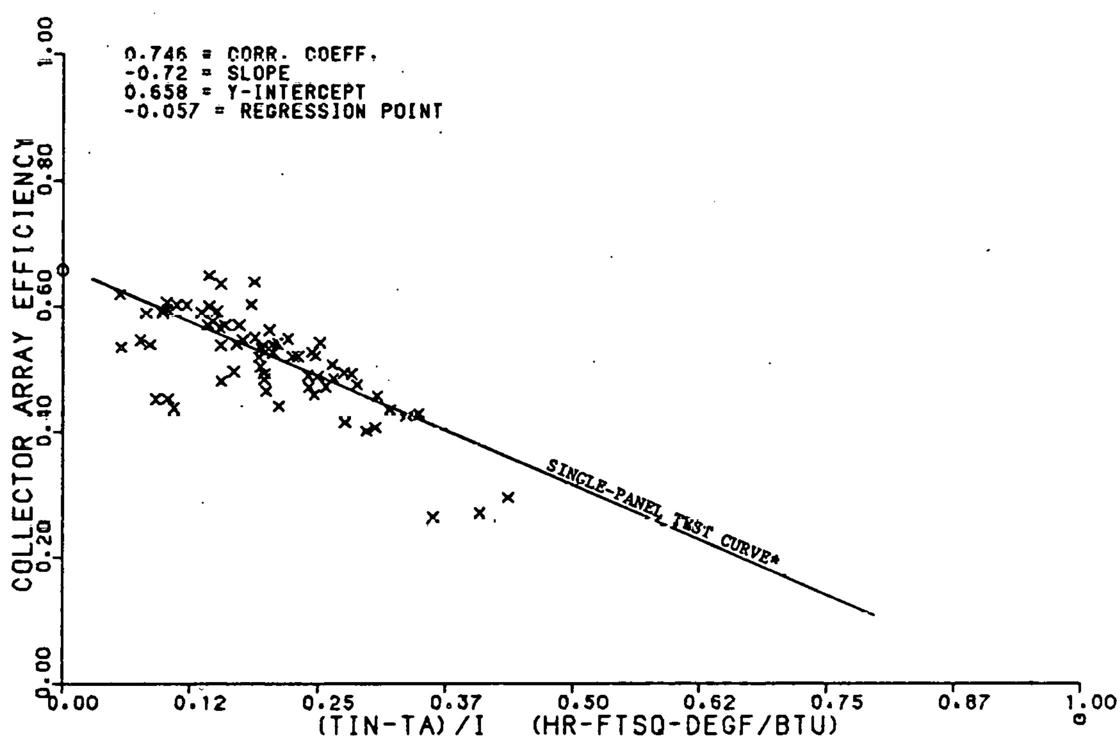
*SERI STR254-1515, July 1983

Figure 12. Collector Array Efficiency
Tucson Job Corps Center
April 1985



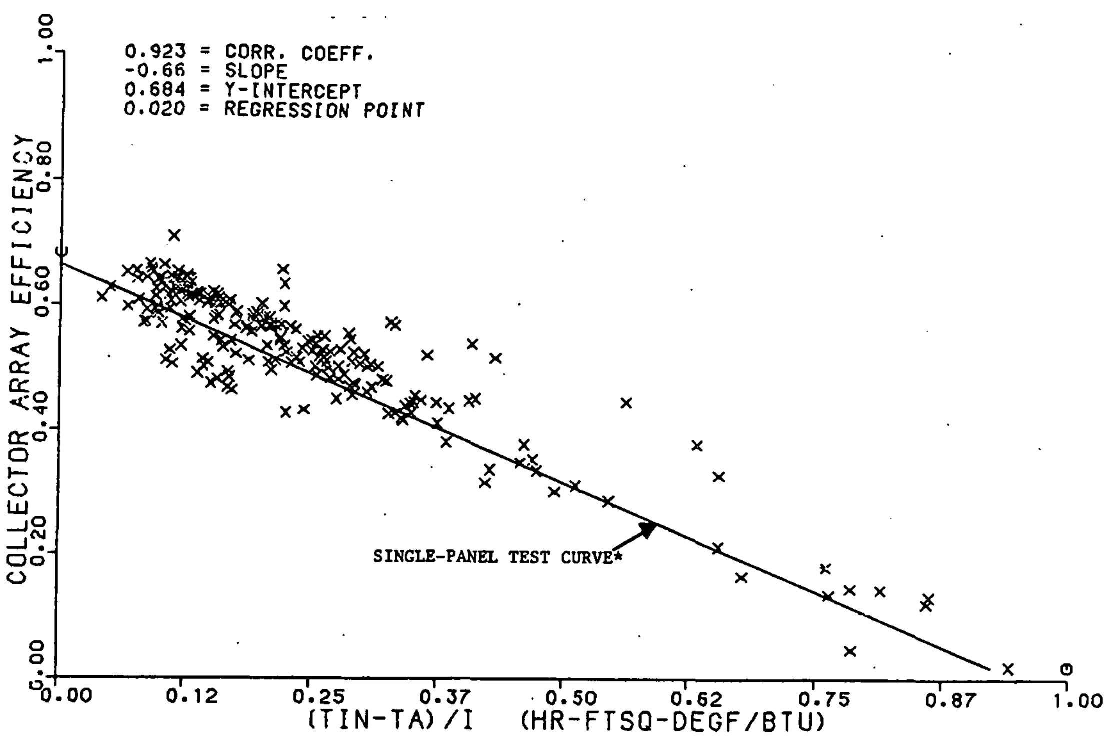
*SERI STR254-1515, July 1983

Figure 13. Collector Array Efficiency
Tucson Job Corps Center
May 1985



*SERI STR254-1515, July 1983

Figure 14. Collector Array Efficiency
Tucson Job Corps Center
June 1985



*SERI STR254-1515, July 1983

Figure 15. Collector Array Efficiency
Tucson Job Corps Center
July 1985

It is unusual for a collector array to perform as well as a single panel. The reasons for poorer performance are usually due to collector array pipe losses, flow imbalance effects and other losses. At the Tucson Job Corps center, the collector array pipe losses are small due to the small quantity of array pipes, good insulation and warm ambient temperatures. There do not appear to be any serious flow balance effects and the flush mounting of the collectors to the roof reduces back losses and convective heat loss effects due to wind.

3. Storage. The performance of the 2,200-gallon storage tank is shown in Table 4. There were 246 million BTU into storage and 193 million BTU used from storage. The storage efficiency was 78% and the average storage temperature was 124°F. With a change of only 0.11 million BTU in energy stored in the tank over the monitoring period, storage losses accounted for 52.4 million BTU. These storage losses resulted in an effective heat transfer coefficient of 0.76 BTU/hr-°F-ft^2 or an R value of 1.3. There is a high degree of uncertainty associated with this value since it is derived from the difference between two large numbers.

The storage tank is insulated with four inches of foam which has a theoretical R of 25. The table below shows the estimated theoretical losses from various parts of the storage tank system.

Mode	Theoretical UA (BTU/hr°F)
Insulated Tank	10.1
Tank Skirt	7.8
Uninsulated Tankhead	25.1
Manway	2.5
Pad	1.4
Connected Pipe	1.1
	48 BTU/hr°F

Effective Theoretical Loss Rate $\frac{48 \text{ BTU/hr°F}}{271.4 \text{ ft}^2}$ = 0.177 BTU/hr°F ft^2 or R5.65

The difference between the measured and theoretical loss rate is suspected to be partially due to thermosiphoning and to uncertainty in the measured storage losses. Thermosiphoning was indicated by sensor T100 (collector supply temperature) which stayed warm all night. However, sensors T150 (collector return temperature), T110 (collector plate temperature), and T101 (storage supply temperature) did not show any evidence of thermosiphoning. An estimate of the thermosiphoning loss was about 12 million BTU in five months. (This is derived from an estimate of storage losses using the difference between the theoretical value above and the measured losses.) Coincidentally, this thermosiphon loss rate is nearly equivalent to the thermosiphon loss rate observed at the Gainesville, Florida solar site.

Table 4. STORAGE PERFORMANCE

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE (STEI)	ENERGY FROM STORAGE (STEO)	CHANGE IN STORED ENERGY (STECH)	STORAGE EFFICIENCY (%) (STEFF)	AVERAGE STORAGE TEMPERATURE (°F) (TST)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/hr°F-ft²) (STPER)	LOSS FROM STORAGE (STLOSS)
NOV	17.3E	16.0E	-0.66E	89E	102E	0.12E	1.96E
JAN	15.0E	6.6E	0.22E	45E	83E	0.97E	8.20E
MAR	36.6	33.5	0.15	92	118	0.15	2.95
APR	47.0	41.8	0.47	90	131	0.25	4.73
MAY	46.8E	40.9E	0.06E	88E	136E	0.32E	5.84E
JUN	42.0E	31.3E	0.42E	75E	152E	0.50E	10.3E
JUL	41.0	23.2	-0.55	55	147	0.95	18.4
TOTAL	246E	193E	0.11E	-	-	-	52.4E
AVERAGE	35.1E	27.6E	0.02E	78E	124E	0.76E	7.48E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% but more than 40% measured data.
See Appendix B for bridging methodology used.

Since 71% of the tank losses occur from the uninsulated tank head, skirt and pad, a substantial reduction in losses is possible by insulating the tank head and manway. The estimated savings from insulating the entire tank with 4" of foam are 7.3 million BTU for the seven month monitoring period.

The storage losses were quite variable through the months and depended on system operation. For example, the losses in January were very high due to continuous operation of the collector pump. Continuous pumping keeps the storage tank mixed, causing higher temperatures in the region of the tank skirt and uninsulated tank bottom. Note that 71% of the tank losses occur from this region. In April and May, storage losses increased when the DHW load side pump returned water through the storage tank. Although the flow rate of the DHW recirculation loop is only 7.7 gpm, this warm water entering the bottom of the storage tank causes destratification. In June, the load was reduced and that resulted in a higher storage temperature and more losses. In July, there was a combination of lowered loads and continuous operation of the collector pump for about 20 days during the month which resulted in larger storage losses.

Since this system was designed, some new design philosophy has called for smaller storage tanks on some DHW systems. A smaller tank costs less, loses less solar energy and works well when the load is concurrent with solar energy collection. However, at Tucson the loads occur in the evening and early morning after solar collection has ceased for the day. Furthermore, the magnitude of the average demand is 2300 gallons per day. Therefore, the solar tank is sized to meet the average demand.

A problem of streaming in the storage tank was solved by a change in the dip tube configuration. A tee and two 45° elbows were improperly attached to the dip tube and imparted a swirling motion to the storage tank fluid. This change was successful in preventing streaming as evidenced by the close agreement of all three storage tank sensors.

4. Hot Water Load. The solar energy system supplied 193 million BTU to the 285 million BTU hot water load (HWL) for a solar fraction of 68%. The hot water demand (HWDM) (energy required to raise the hot water used from the supply water temperature to the hot water temperature) was 218 million BTU and the demand solar fraction was 69%. The auxiliary system provided 91.6 million BTU. There were 493,200 gallons of hot water used at a average temperature of 130°F. The DHW subsystem performance is shown in Table 5.

The load side pump P4 was active from January 11th to February 13th, March 19th to June 12th and after July 8th. Apparently the motor coupling broke in February but it isn't known why the pump was not active at the other times. The load side recirculation losses were about 5 million BTU per month during the winter, about 4 1/2 million BTU per month in the spring and about 2 million BTU per month in the summer. These losses are partially made up with solar energy and may have contributed to higher solar fractions during the winter and spring. Since there were no complaints when the pump was off, one can conclude that load side pump P4 is unnecessary. Therefore, turning off the load side pump would save between 2 and 5 million BTU per month. The fuel savings are estimated from considering that solar energy supplied the same fraction of the load side pump losses as the load, 68%. Therefore estimated losses are 23 million BTU, of these 7.4 million

Table 5. DOMESTIC HOT WATER SUBSYSTEM PERFORMANCE

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD (HWL)	SOLAR FRACTION OF LOAD (%) (HWSFR)	HOT WATER DEMAND (HWDM)	SOLAR FRACTION OF DEMAND (%) (HWDSFR)	SOLAR ENERGY USED (HWSE)	AUXILIARY THERMAL USED (HWAT)	AUXILIARY FOSSIL FUEL (HWAF)	SUPPLY WATER TEMPERATURE (°F) (TSW)	HOT WATER TEMPERATURE (°F) (THW)	HOT WATER CONSUMPTION (Gallons) (HWCSM)
NOV	43.0E	37E	39.7E	51E	16.0E	27.0E	39.3E	73E	129E	86,300E
JAN	44.5E	15E	34.5E	19E	6.6E	37.9E	49.3E	70E	125E	75,000E
MAR	51.5	62	40.2	67	33.5	18.0	25.6	73	132	83,400
APR	46.8	89	35.6	88	41.8	5.0	7.4E	77E	136	73,200
MAY	43.3E	94E	29.4E	94E	40.9E	2.4E	4.0E	79E	139E	58,800E
JUN	32.6E	96	22.6E	98E	31.3E	1.3E	1.9E	83E	124E	66,800E
JUL	23.2	100	16.0	100	23.2	0.0	0.0	84	123	49,700
TOTAL	285E	-	218E	-	193E	91.6E	127E	-	-	493,200E
AVERAGE	40.7E	68E	31.1E	69E	27.6E	13.1E	18.2E	77E	130E	70,500E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% but more than 40% measured data.
See Appendix B for bridging methodology used.

BTU were made up by the auxiliary boiler and savings would be 12 1/3 million BTU using an assumed 60% boiler efficiency.

The auxiliary system was shutdown on June 20, but little auxiliary energy was used after June 8. Without the auxiliary system to maintain the water temperature, the delivered hot water temperature dropped. The tempering valve setpoint was changed from 160°F to 122°F on June 17th. This accounts for the change in hot water temperature from an average of 132°F to 124°F in June and July.

The effect of the change in the hot water setpoint was estimated by F-Chart to equal a 30 million BTU per year reduction in load. Solar energy used would increase by 21.3 million BTU per year.

One method of reducing losses on future designs for hot water heating of dormitories would be to reduce the DHW auxiliary tank to say 100 gallons. Then the boiler becomes essentially an in line heater and auxiliary losses can be reduced. An estimate of the savings realized by using an in line boiler is 4.1 million BTU over the monitored period. Note that this is perhaps 12% of the total auxiliary losses.

Figure 16 shows a plot of the monthly average hourly hot water consumption during the month of March. The pattern of hot water usage at the Job Corps Center tends to promote good solar energy utilization because about 68% of the collected solar energy was used before midnight. However, the peak usage hours were between five and seven AM. It seems likely that changing the timing of the peak loads to the evening would improve the demand solar fraction to 73%. This would represent an increase of 4% in demand solar fraction or an increase of 9 million BTU in the total solar energy used. Since a 9 million BTU increase in solar energy utilization is possible simply from a shift in load usage patterns, this type of change in usage should be encouraged.

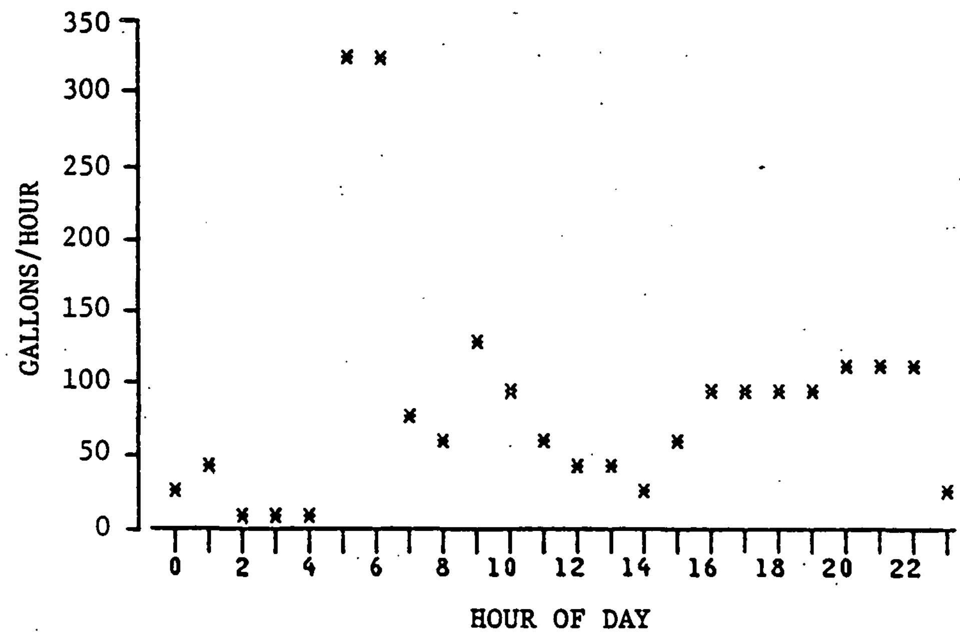


Figure 16. Monthly Average Hourly Hot Water Consumption
Tucson Job Corps Center March 1985

Figure 17 shows a graph of the hourly hot water load for the week of March 3rd through the 9th of 1985. This is a typical week at the Job Corps Center. Note that there is a definite diurnal pattern during the week with the peak morning loads occurring between 5 and 7 AM. The peak evening loads are not so large and occur between 4 to 10 PM. The weekends have a more continuous load pattern with a late morning peak and a somewhat lower and larger evening peak.

The daily loads shown in Figure 18 illustrate the fairly constant load pattern occurring at Tucson. The magnitude of the load is greater during the winter due to colder ground water temperature and more students. Monthly loads are shown in figure 19. These peak in March, perhaps because the ground water is nearly at its coldest point and because the delivered water temperature is higher. During June, the tempering valve setpoint was changed from 160°F to 122°F; also some students left. These factors reduced the load.

The water consumption rates in gallons and gallons per student are summarized below.

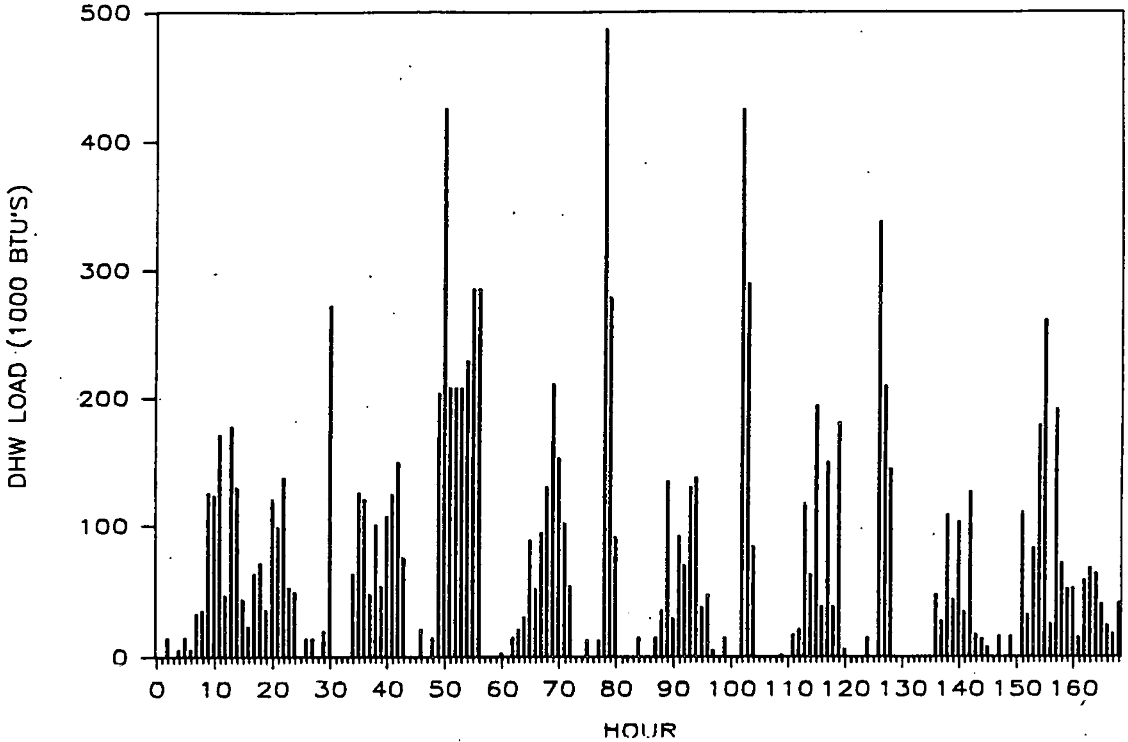


Figure 17. Hourly Hot Water Load
Tucson Job Corps Center March 3 through 9, 1985

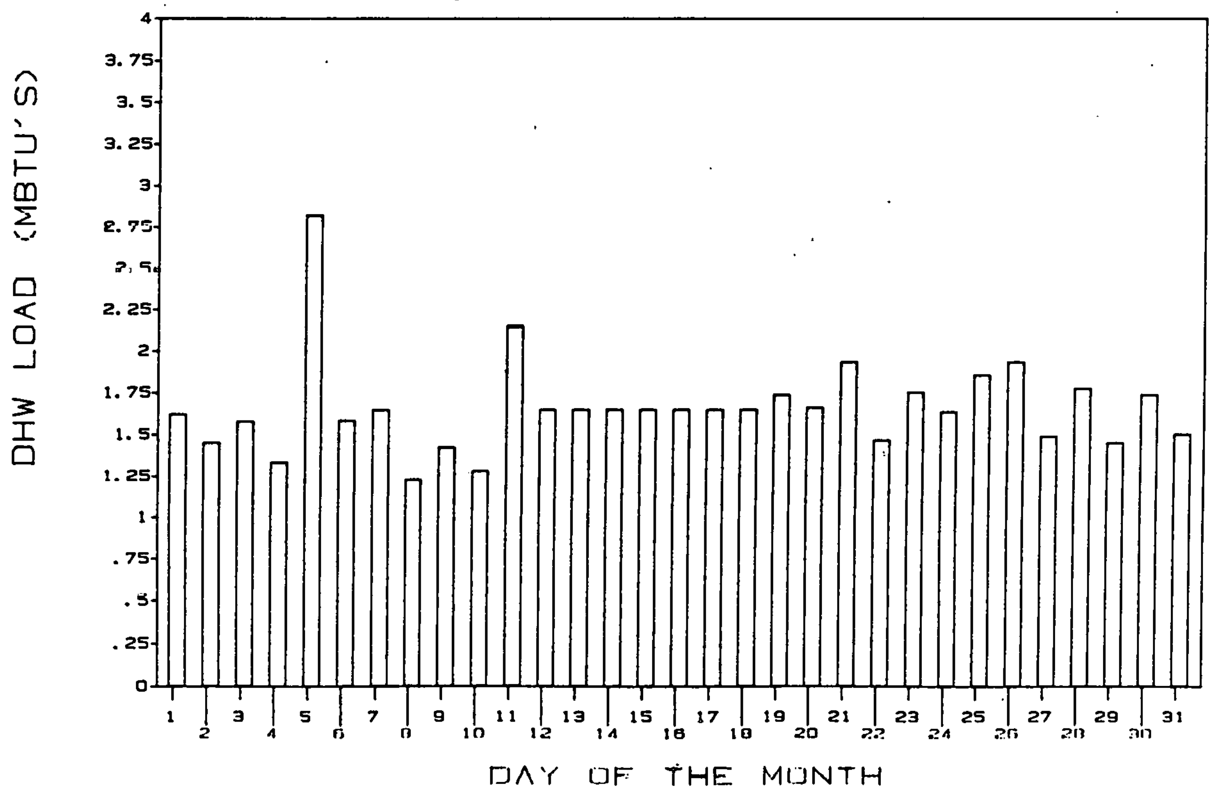


Figure 18. Daily Hot Water Load
Tucson Job Corps Center, March, 1985

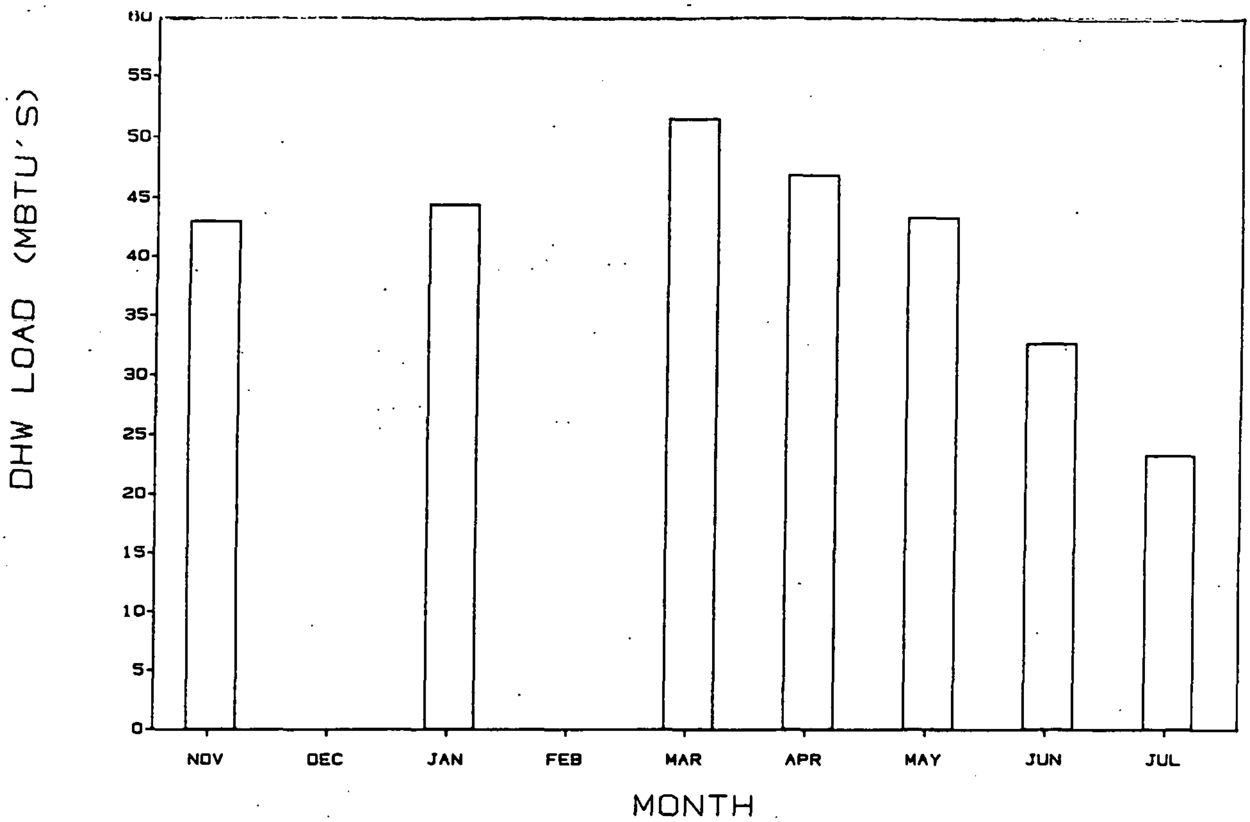


Figure 19. Monthly Hot Water Load
Tucson Job Corps Center November 1984 through July 1985

	Tucson Measurements					ASHRAE Handbook	
	Gallons			Gallons/Student		Gallons/Student	
	Monthly	Daily	Hourly	Daily	Hourly	Daily	Hourly
Average	70,500	2305	96.0	11.5	0.5	13.1	-
Minimum	49,700	732	0	3.7	0	-	-
Maximum	86,300	5277	541	26.4	2.7	22.0	3.8

The average daily consumption is 2305 gallons, just slightly more than the storage tank size. The implication is that solar energy could supply most of the hot water on a good sunny day. The daily normalized measurements agree quite closely with the ASHRAE Handbook (Reference 14) but the normalized maximum hourly measurement is only 71% of the ASHRAE value. These comparisons suggest that a design based on the ASHRAE value will be oversdesigned for the maximum hourly requirements and quite adequate for the daily requirements. However, the maximum hourly value will be used to determine the pipe and boiler sizes which will be major cost components of the system. The solar system, including the storage tank, should be designed based on the daily value. At Tucson, the measured average daily value is 88% of the ASHRAE value. Since water consumption varied by as much as 20% from the average sizing estimate, the solar system using the ASHRAE value for average daily water consumption per student is satisfactory.

5. Parasitic Power and Coefficient of Performance. The only parasitic power used by the solar system is for the collector pump. The collector pump operating energy of 5.87 million BTU is shown in Table 6. The months of January, March and July have high operating energies because the collector pump was running continuously for many days during the month. (See Hardware and Instrumentation Problems [Section V.C.1] for more details on the cause of this problem.)

Table 6. SOLAR OPERATING ENERGY

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU, unless otherwise indicated)

MONTH	ECSS OPERATING ENERGY SOLAR-UNIQUE	TOTAL SOLAR OPERATING ENERGY
	(SCOPE)	(SYSOPE1)
NOV	0.32E	0.32E
JAN	1.03E	1.03E
MAR	0.92	0.92
APR	0.59	0.59
MAY	0.61E	0.61E
JUN	0.84E	0.84E
JUL	1.56	1.56
TOTAL	5.87E	5.87E
AVERAGE	0.84E	0.84E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% measured data but more than 40%. See Appendix B for bridging methodology used.

Table 7 shows the solar coefficient of performance for the solar system and the collector subsystem. Coefficient of performance is the ratio of energy collected or used to the energy required to transport the solar energy. The collector COP of 42 compares favorably to other large DHW solar systems. The system COP (33) is less than the collector COP because it is the ratio of solar energy used to the collector pump operating energy. The months of April and May are probably the most representative of the COP during normal collector operation.

Table 7. SOLAR COEFFICIENT OF PERFORMANCE

TUCSON JOB CORPS CENTER
NOVEMBER 1984, JULY 1985

MONTH	SOLAR ENERGY SYSTEM	COLLECTION SUBSYSTEM
	(SEL) / (SYSOPE1)	(SECA) / (CSOPE)
NOV	50	54
JAN	6	15
MAR	36	40
APR	71	80
MAY	67	77
JUN	37	50
JUL	15	27
WEIGHTED AVERAGE	33	42

For a description of acronyms in parentheses, refer to Appendix A.

6. System Performance. System performance of the Tucson Job Corps Center is shown in Table 8. The system load of 285 million BTU was met by 193 million BTU of solar energy (this is 92% of the amount predicted by F-Chart for the monitoring period) and 127 million BTU of fossil fuel. About 78% of the 248 million BTU of solar energy collected was utilized, this level of utilization is about average compared to other NSDN sites. Energy savings were 322 million BTU of fossil fuel based on an assumed auxiliary boiler efficiency of 60% at a cost of 5.87 million BTU of electricity. The system solar fraction was 68% of the load versus a 74% solar fraction predicted by F-Chart for the monitoring period. A total of 28% of the solar energy incident on the collector was delivered to the load. The energy flow diagram shown in Figure 20 summarizes the main energy transfers within the Tucson solar system.

7. F-Chart Comparison. A comparison of the measured system performance versus an F-Chart (Version 5.5) calculation is presented in Table 9.

Table 8. SOLAR SYSTEM THERMAL PERFORMANCE

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY FOSSIL	AUXILIARY ENERGY THERMAL	TOTAL OPERATING ENERGY	ENERGY SAVINGS FOSSIL	ENERGY SAVINGS ELECTRICAL	SOLAR FRACTION (%)
	(SECA)	(SYSL)	(SEL)	(AXF)	(AXE)	(SYSOPE)	(TSVF)	(TSVE)	(SFR)
NOV	17.4	43.0E	16.0E	39.3E	N/A	1.71E	26.7E	-0.32E	37E
JAN	15.4E	44.5E	6.6E	49.3E	N/A	2.47E	11.0E	-1.03E	15E
MAR	37.1	51.5	33.5	25.6	N/A	2.09	55.8	-0.92	62
APR	47.3	46.8	41.8	7.4E	N/A	2.05	69.7	-0.59	89
MAY	47.0E	43.3E	40.9E	4.0E	N/A	1.41E	68.2E	-0.61E	94E
JUN	42.4E	32.6E	31.3E	1.9E	N/A	2.19E	52.2	-0.84E	96E
JUL	41.8	23.2	23.2	0.0	N/A	1.56	38.7	-0.56	100
TOTAL	248E	285E	193E	127E	-	13.5E	322E	-5.87E	-
AVERAGE	35.5E	40.7E	27.6E	18.2E		1.93E	46.0E	-0.84E	68E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E Indicates estimated monthly value based on less than 90% but more than 40% measured data. See Appendix B

* Indicates less than 40% measured data available.

Table 9. COMPARISON OF EXPECTED TO MEASURED ANNUAL PERFORMANCE

TUCSON JOB CORPS CENTER

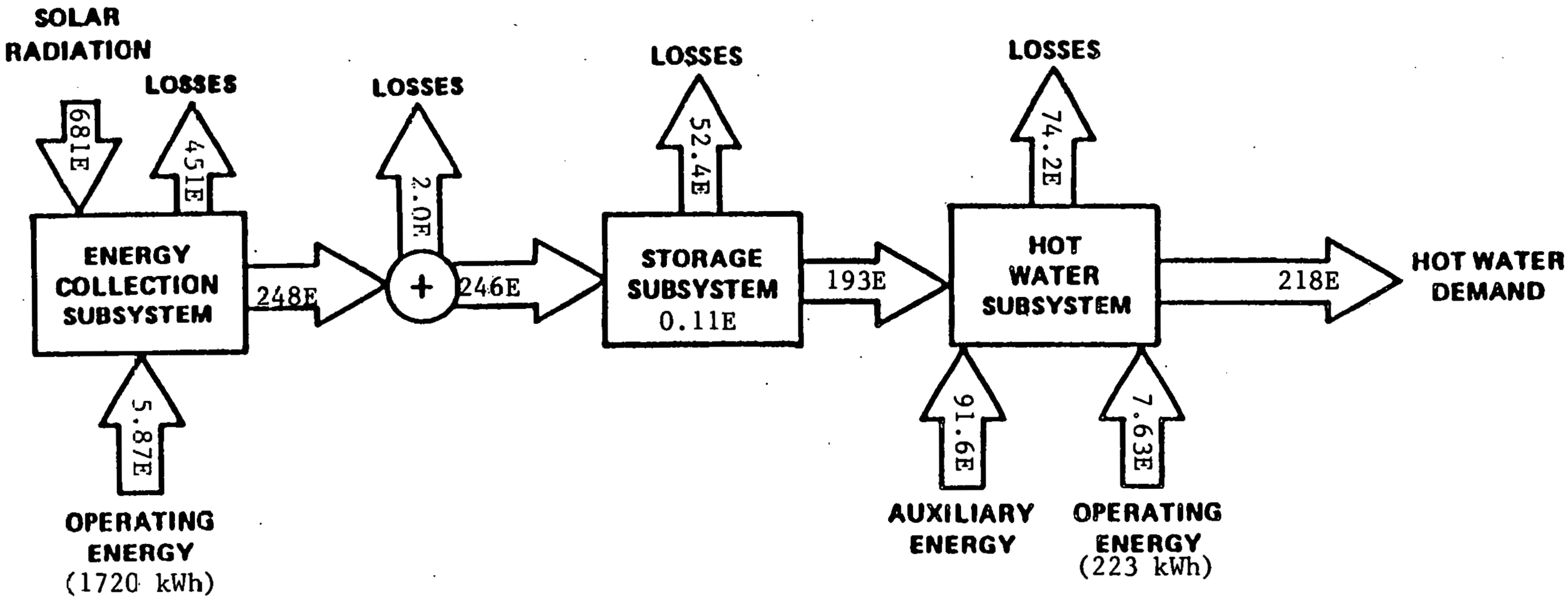
(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	MEASURED COLLECTED SOLAR ENERGY	SOLAR ENERGY USED PREDICTED	SOLAR ENERGY USED EXTRAPOLATED	SOLAR ENERGY USED MEASURED	SOLAR FRACTION (%) PREDICTED	SOLAR FRACTION (%) EXTRAPOLATED	SOLAR FRACTION (%) MEASURED
JAN	84	15.4E	27.2	29.1	6.6	61	66	15
FEB	89	-	32.5	34.6	-	66	71	-
MAR	99	37.1	34.0	36.4	33.5	65	70	62
APR	106	47.3	35.5	37.6	41.8	75	80	89
MAY	109	47E	35.0	37.1	40.9	81	86	94
JUN	108	42.4E	31.0	32.6	31.3	94	99	96
JUL	101	41.0	23.2	23.4	23.2	99	100	100
AUG	108	-	26.2	26.2	-	100	100	-
SEP	106	-	30.6	31.1	-	98	100	-
OCT	87	-	23.5	24.8	-	85	90	-
NOV	75	17.4E	23.7	25.6	16.	54	59	37
DEC	83	-	23.8	25.1	-	84	89	-
TOTAL	1155	387E	346	364	193			
AVERAGE	96.3	55.3	28.9	30.3	84	77	81	N/A

COLLECTION SUBSYSTEM EFFICIENCY - 36%

STORAGE EFFICIENCY - 78%

HOT WATER SOLAR FRACTION - 68%



E - DENOTES ESTIMATED VALUE.

Figure 20. Energy Flow Diagram for Tucson Job Corps Center
November 1984, January, March through July 1985
(All values in million BTU, unless otherwise indicated)

Predicted values are the expected system performance values in Table 1 (load minus aux). Values used in the "extrapolated" column of Table 9 were obtained by use of an F-Chart calculation using measured system parameters and weather data when available and long-term weather data and average monthly measured system values for those months when no measured data was available. The conditions and assumptions used in the data input for F-Chart are given in Appendix F. The F-Chart input parameters used to extrapolate annual performance are given in Table F-2, Appendix F and the F-Chart model results are presented in Table 10. The F-Chart extrapolation of annual solar energy used was 364 million BTU.

Table 10. F-CHART EXTRAPOLATED ANNUAL PERFORMANCE

TUCSON JOB CORPS CENTER

*** WATER STORAGE SYSTEM ***

	SOLAR MMBTU	HEAT MMBTU	DHW MMBTU	AUX MMBTU	F
JAN	84.0	0.0	44.4	15.3	0.66
FEB	93.1	0.0	49.0	14.4	0.71
MAR	99.0	0.0	52.3	15.9	0.70
APR	106.0	0.0	47.2	9.6	0.80
MAY	109.0	0.0	43.3	6.2	0.86
JUN	108.0	0.0	32.9	0.3	0.99
JUL	101.0	0.0	23.4	0.0	1.00
AUG	115.4	0.0	26.2	0.0	1.00
SEP	113.6	0.0	31.1	0.0	1.00
OCT	89.5	0.0	27.6	2.8	0.90
NOV	75.0	0.0	43.5	17.9	0.59
DEC	87.1	0.0	28.3	3.2	0.89
YR	1180.6	0.0	449.1	85.5	0.81

SOLAR is the monthly total solar radiation incident on the collector surface in MMBTU (million BTU).

HEAT is the monthly space heating load (MMBTU).

DHW is the monthly water heating (MMBTU).

AUX is the monthly total auxiliary energy required to supply the domestic water heating load (MMBTU).

F is the fraction of the water heating load which is supplied by solar energy.

Note that the extrapolated F-Chart calculation shows that the measured system performs better than the prediction by 18 million BTU. This is due to the fact that the measured collector slope parameter is slightly better than the ASHRAE valve. All other parameters were the same for the two calculations. Perhaps also of interest is that the predicted F-Chart calculation was adequate to account for system losses (which included the load side pump) by increasing the auxiliary tank UA from 19 BTU/hr-°F to 180 BTU/hr-°F. Changes were also made to the environment temperature to make the F-Chart results more nearly match the measured loads.

To some degree, F-Chart can be used to predict the losses caused by solar system malfunction. From November 26, 1984 until May 1, 1985 the collector system was not operating or was only partially operating. A comparison of measured data to F-Chart extrapolated data from November, December and January shows that the potential collected solar energy was 79.8 million BTU. The actual collected energy was 22.6 million BTU or 28% of F-Chart. The month of December was counted although there was not much measured data because the solar system was shut down; February was not counted because of data logger problems. It is important to note that although the collector pump ran continuously for 15 days in January nearly 23% of the possible solar energy was collected and used.

There were also 10 days of continuous collector pump operation in March. Since the weather was warmer, this problem caused a loss of only 8%. During 22 days of continuous collector pump operation in July, the comparison of F-Chart and measured data indicates no loss. The actual loss is perhaps less than 10%.

8. <u>Savings</u>. The energy savings for the seven months monitored were 322 million BTU of fossil fuel at a cost of 5.87 million BTU of electricity. The savings are presented in Table 11. The fossil savings were calculated assuming a boiler efficiency of 60%. These good savings resulted from good solar energy collection and utilization.

The total system normalized cost was \$68,658 or \$38.62/ft^2 of collector (Reference 15). Dividing the normalized installation cost by the annual solar energy delivered by a system in good operational condition yields a cost of \$189/million BTU. The normalized cost represents an extrapolation of the actual cost to construct the system as though the project were competitively bid and awarded for a private commercial owner. The normalization also moves all cost factors into the year 1985. By using the 1985 NBS Energy Price Handbook (Reference 16) for Region 9, which includes Arizona, an estimate of the dollar energy savings is possible. During the seven months monitored, the system saved natural gas worth \$2,035 at an electricity cost of \$116 for a total savings of \$1,919. The extrapolated annual savings are equivalent to a \$3,834 savings in natural gas at an electricity cost of \$220 for a net annual savings of \$3,614 or \$2.18 per ft^2.

The cost per square foot of \$38.62 was among the lowest of the monitored SFBP solar systems. The storage tank was below average in cost but perhaps that was because the storage enclosure was added some time after the solar system was operational. Instrumentation and controls were about \$2000 more than the other DHW systems due to the added complexity of the lead-lag pump arrangement and the freeze protection subsystem which consisted of a recirculation and a drainout mode.

9. <u>System Availability</u>. During the period from November 1984 through July 1985 the solar system was available for energy collection 223 days of the 273 days or 82% of the time. The system was unavailable due to the freezeup from November 26, 1984 through January 2, 1985. However, the

Table 11. ENERGY SAVINGS

TUCSON JOB CORPS CENTER
NOVEMBER 1984 THROUGH JULY 1985

(All values in million BTU)

MONTH	SOLAR ENERGY USED (SEL)	DOMESTIC HOT WATER ELECTRICAL (HWSVE)	DOMESTIC HOT WATER FOSSIL FUEL (HWSVF)	ECSS OPERATING ENERGY SOLAR-UNIQUE (CSOPE)	NET ENERGY SAVINGS ELECTRICAL (TSVE)	NET ENERGY SAVINGS FOSSIL FUEL (TSVF)
NOV	16.0E	-0.32E	26.7E	0.32E	-0.32E	26.7E
JAN	6.6E	-1.03E	11.0E	1.03E	-1.03E	11.0E
MAR	33.5	-0.92	55.8	0.92	-0.92	55.8
APR	41.8	-0.59	69.7	0.59	-0.59	69.7
MAY	40.9E	-0.61E	68.2E	0.61E	-0.61E	68.2E
JUN	31.3E	-0.84E	52.2E	0.84E	-0.84E	52.2E
JUL	23.2	-1.56	38.7	1.56	-1.56	38.7
TOTAL	193E	-5.87E	322E	5.87E	-5.87E	322E
AVERAGE	27.6E	-0.84E	46.0E	0.84E	-0.84E	46.0E

For a description of acronyms in parentheses, refer to Appendix A.

All values are rounded to the accuracy associated with the instrumentation used.

E indicates estimated monthly value based on less than 90% but more than 40% measured data. See Appendix B for bridging methodology used.

system ran continuously (without control) for 16% of the monitoring period. The continuous pump operation occurred when the collector pump control switched to the "lag" pump for several days. The worst occurrence of continuous pump operation was during July.

B. RELIABILITY AND MAINTAINABILITY

1. Component Failures. There were three solar system component failures during the monitoring period. In November, a short in the freeze thermostat wiring blew a fuse on the controller and several collector panels froze because the backup ground water flush freeze protection system had been deactivated.

The flush through freeze protection method may not be reliable enough even if it is not disabled because of corrosion problems with the drainout valve. There are several alternative freeze protection schemes with antifreeze and drainback being most common. The closed loop drainback system is perhaps the better choice since the system cost is lower.

A collector pump failed in March and was eventually replaced. Also in March, the DHW recirculation pump coupling was repaired. In September, prior to the start of the monitoring period, the collector controller was replaced.

2. Maintenance Time/Month. The actual amount of maintenance time is unavailable but the time can be estimated from the down time. There were about 12 days of maintenance required during the monitoring period. This is

an average of 14 hours/month. This will reduce performance by an average of 2 million BTU per month.

C. HARDWARE AND INSTRUMENTATION PROBLEMS

1. Site Hardware Problems. One of the major system problems during the monitoring period was a collector freeze up on November 26, 1984. Five collector panels were damaged. Normally, the collectors are protected from freezing by circulation of storage water when the collector freeze thermostats signify a plate temperature of 34°F or less. The freeze up occurred because some of the freeze thermostat wiring shorted out and blew a fuse in the controller. The secondary freeze protection mode of city water flush through was deactivated due to corrosion and removal of the flush valve. The collector system was out of operation from November 26, 1984 through January 9, 1985. The system was repaired by removing the five damaged collector panels which reduced the collector area to 1,659 ft^2. However, the controller was not completely repaired until March 1, 1985. Since the automatic freeze protection system was inoperative, the site personnel were instructed to manually run the pumps all night to preclude system freeze damage. Continuous pumping caused a lot of energy rejection at night and maintained a mixed storage tank.

Storage losses were high in January due to the mixed tank resulting from the extended pump operation. Normal system operation causes the tank to be well mixed during the day while the collector pump is on. However, most of the hot water is used after the collector pump stops in the evening and before the collector pump starts in the morning. This usage pattern quickly fills the bottom of the storage with cold water and effectively insulates the lower part of the tank and saddle from the warm storage water, greatly reducing saddle conductive losses and radiant losses from the saddle and uninsulated lower tank head.

The large storage losses in June were also partially caused by the same continuous collector pump operation and by the much larger saddle to pad temperature difference.

A collector pump failed in March but caused only a small impact on performance because the controller switched to the backup pump. However, when the backup pump was switched in, it ran continuously for several days. This is normal. The continuous operation of the system is designed to alert the system operator that the lead pump has failed.

A long-standing system problem was fixed in late March; the coupling on the DHW recirculation pump was repaired so recirculated DHW return water could be preheated by the solar system. The recirculation loop on the DHW system started circulating through the solar storage tank on April 3, 1985 and stopped circulating on June 12, 1985 and then started circulating DHW return water through the storage after July 8th.

The collector pump ran continuously for three different times in June and July, but no lead pump failure occurred. This apparent control failure continued to plague the Tucson Job Corps system throughout August and September. The problem was finally resolved after the monitoring period ended when it was discovered that the changeover logic from the lead to the lag pump was misunderstood by the system operators.

There is a short time delay, 0-1 minute, on the changeover switch for the lead to lag pump. Continuous operation of the lag pump was either misunderstood or disregarded by the system operator because there was never any detectable failure on the lead pump. The switch over to the lag pump was caused by a very short time delay setting in the controller, about 1/2 second, which was frequently tripped when the lead pump was slow to start.

2. Site Instrumentation Problems. The solar monitoring system was also prone to problems. During the monitoring period, 25% of the data was lost due to failure of the site datalogger. After a series of failures in October 1984, the datalogger was replaced with a newer model on November 12, 1984. On December 5, 1984 the tape recorder was replaced and sensor T110 was disconnected. T110 was disconnected because the collector panel with the plate sensor suffered freeze damage and was bypassed. In February, the datalogger again had tape recorder problems and after several resets by site personnel the problem disappeared. T110 was reconnected on February 25, 1985. From March 13-19,1985 all of the data from flow totalizers and elapsed timers was lost due to the loss of calibration coefficients from the datalogger memory. On June 11, 1985, the datalogger tape recorder was replaced and T200 was moved from the storage tank inlet to a point about six feet upstream in the recirculation return line in an effort to better measure the storage inlet temperature when the recirculation pump is on. Moving the sensor did not make any improvement in the measurements of this temperature, therefore this sensor was used to estimate load recirculation loop losses but not in the calculation of any major performance factors. Again, on June 25, 1985, the datalogger tape recorder was repaired.

In months where less than 90% of the data was collected, the data is flagged with an E for estimated.

T150 failed January 30, 1985. It began operating properly February 12, 1985, but site personnel said they did not repair it.

The ambient air temperature sensor T001 was located near a roof vent which produced as much as an 8°F bias on hot days but had little effect during the winter months.

D. SIGNIFICANT EVENTS

Below is a summary of key events at the Tucson Job Corps Center solar site during the monitoring period.

DATE	EVENT
8/25/82	System acceptance test performed by ETEC.
9/11/84 - 9/15/84	Site checkout.
10/1/84	Datalogger failure.

DATE	EVENT
10/5/84	Datalogger failed.
11/12/84 - 11/15/84	New Datalogger (MOD IIA) installed.
11/26/84	Collector system froze.
12/5/84 - 12/6/84	Datalogger repaired. T110 shorted out.
1/9/85	Damaged collector panels were removed and bypassed. Collector system back on line but collector pump runs continuously.
1/24/85 - 1/30/85	Collector shutdown for leak testing. T150 down. Controller was not repaired.
2/1/85 - 2/6/85	Datalogger down due to tape recorder.
2/12/85	T150 repaired itself. Datalogger failed.
2/25/85	Datalogger reset by site personnel.
3/1/85	Site visit by ETEC to conduct a thermal survey of the solar system. Collector control repaired. Collector pump at normal operation.
3/9/85 - 3/13/85	Collector pump ran continuously because one of the collector pumps failed.
3/13/85 - 3/19/85	Datalogger lost flow totalizer calibration coefficients.
3/16/85	Johnson control personnel at the site to adjust the solar controller.
3/19/85	Coupling on DHW recirculation pump repaired. (This coupling was broken before the monitoring period.)
3/27/85 - 4/1/85	Collector System being repaired. Collector pump runs continuously.
6/5/85	Datalogger failed.
6/11/85 - 6/13/85	Datalogger repaired. Vitro technician assisted ETEC personnel with flow rate check and controller calibration. T200 was moved 6' to a section of inlet pipe with more stable flow.
6/13/85 - 6/18/85	Collector pump runs continuously. T351 bridge replaced and not recalibrated.
6/18/85	Auxiliary furnace shut off.

DATE	EVENT
6/19/85	Datalogger failed.
6/25/85 - 6/27/85	Datalogger tape recorder and tape control repaired.
7/6/85 - 7/12/85	Collector pump runs continuously.
7/17/85 - 7/31/85	Collector pump runs continuously.
8, 9 & 10/85	Data collected during August, September and October for special studies, but no monthly report prepared.
11/3/85	Data collection terminated.
12/10/85	Instrumentation decommissioned - SDAS removed.

Section VI

COMPARISON TO NSDN SITES

In this section the performance of the Tucson Job Corps Center Solar System is compared to six large commercial NSDN hot water solar systems and to the Honolulu Ramada Inn solar system (Reference 17) in particular.

While comparison of the performance of this SFBP solar system to that of NSDN solar systems operating under different environmental conditions and loads is of limited value, it does provide a reference point by which to judge the performance of the system.

The 1981-1982 DHW comparative report contains six (Reference 18) commercial solar hot water systems. There were three process hot water systems, an office building, a school and an apartment building. The NSDN average performance is represented by these six commercial systems.

Table 12 presents the performance data for the Tucson Job Corps Center, Honolulu Ramada Inn and the NSDN average.

Table 12. NSDN Performance Comparison

Performance Category	Tucson Job Corps Center (Nov 1984- July 1985)	Honolulu Ramada Inn (July 1986- Mar 1981)	NSDN Average[1]
1. Total Collector Array Efficiency	36	37	21
2. Operational Collector Array Eff.	47	41	34
3. Percent of Incident Solar Energy Delivered to the Load	28	28	15
4. Collection Coefficient of Performance	42	53	29
5. System Coefficient of Performance	33	41	6.7
6. Percent of Collected Solar Energy Delivered to the Load	78	76	71
7. Solar Energy Delivered to the Load per square foot of Collector per day (BTU/ft^2-day)	544	450	217

[1] An average of performance from Oakmead Industries (manufacturing), Cathedral Square (apartment), EROS Data Center (photo processing), Vitro Office), Craftsman Enterprises (Laundry) and Wood Road School (school).

From Table 12, the reader can easily see that the Tucson Job Corps Center performed better than the average NSDN system in all categories. The Tucson Job Corps Center solar system also performed as well as or better than Honolulu Ramada Inn which was a high performing NSDN solar system. Although Tucson had only one percent less collector array efficiency than Honolulu in terms of solar energy delivered to the load, Tucson had two percent more solar energy delivered to the load. Tucson also delivered substantially more solar energy to the load per square foot of collector per day. In total, these performance indices indicate that the Tucson Job Corps Center is a more efficient solar system than the average NSDN Solar DHW System.

Although the performance of solar energy delivered to the load was significantly better at Tucson than at the Honolulu Ramada, the collector freezeup and continuously running collector pump degraded performance. The value of solar energy delivered to the load from the F-Chart extrapolated model was 601 BTU/ft^2-day. This is an improvement of 9% over the measured value and is an estimate of the improvement that could be expected if all problems are repaired.

Section VII

LESSONS LEARNED

The lessons learned fall into two categories, solar system and load/auxiliary. The following lessons learned were observed from the data analysis of the Tucson Job Corps Center but several of these lessons learned apply to other SFBP sites as well.

A. SOLAR SYSTEM

There are a number of important lessons learned from the analysis of this solar system:

- Operators should receive thorough training. Solar System Operators should receive thorough training and documentation in the operation and maintenance of the solar system. The lack of training in operation of the control subsystem and the lack of documentation for the control subsystem resulted in many days of continuous collector pump operation.

- Storage tank stratification improved performance. Storage tank stratification reduced storage losses at Tucson because 71% of storage losses occurred from the uninsulated tankhead.

- Integration of the collectors into the roof improves system performance by reducing losses from the collector panels.

- Storage tank losses can greatly reduce system performance. Care must be taken to fully insulate the entire surface of the tank as well as the tank supports. Thermosiphoning may be prevented in some cases by adding spring tensioned check valves.

- If city water is passed through the system, adequate corrosion protection must be provided for all of the components in the system.

- The system must be provided with an alarm system which alerts the operator when there is a failure and adequately identifies each type of failure.

- The dip tube configuration with a tee and 45° elbow nozzle at each end of the tee was effective in reducing streaming through the storage tank as evidenced by the uniform temperatures throughout the tank when the collector pump was running.

- Measurement of insolation at this site and two other solar sites in Arizona showed insolation levels are below long term values. This points to an important part of the design process for large solar systems which is often overlooked. In order to properly design a solar system, the designer must determine what the solar resource is for the site micro-climate.

- Use of redundant collector pumps is questionable. The use of two collector pumps made it necessary to have a more complex control system and increased the chance for improper system operation.

- Even in mild environments like Tucson, backup freeze protection is required. The use of circulation of storage fluids for freeze protection was not failsafe. The original strategy for a flush through of city water as a second freeze protection measure was not reliable due to corrosion on the drain out valve. A drainback system would be more reliable.

- In order for the F-Chart model to be successfully used to describe system losses from the DHW system, the auxiliary UA value had to be increased to 180 and the environment temperature adjusted so that the F-Chart generated loads would more nearly match the measured loads.

- An independent TRNSYS simulation of the Tucson collector system indicates that a 4% gain in solar energy used is possible by changing the control to a 5°F on and 1°F off setpoint. (Reference 19).

B. LOAD/AUXILIARY

- Load side recirculation may not be required in some DHW systems. The DHW loadside pump was not needed since there were no particular complaints before the pump was repaired in April.

- Knowledge of load size and profile can improve system design. A better load study could be used to improve system sizing, summer operational strategies and F-Chart predictions.

- Where practical, a change in usage patterns can improve system performance. (Use solar energy as soon after it is collected as possible.) Educating the solar energy consumer to change DHW usage patterns could improve solar energy utilization at this site by 3%.

- During the summer months, DHW systems in climates like that at Tucson may not require any auxiliary energy. Although the auxiliary system was shut off in late June, the system operator probably could have shut the auxiliary off in May.

Section VIII

OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

A. OBSERVATIONS

- The Water Storage System F-Chart model can be adjusted to the load side recirculation and system losses if these losses can be estimated. At Tucson these losses were about 10 million BTU per month roughly divided equally between the boiler and auxiliary storage tank and the load side loop. If these load side recirculation losses are added to the UA of the auxiliary storage tank, the F-Chart model will produce good results.

- Summer high limit sensors should be used. Since the solar collector was oversized for the summer load, a summer high limit control sensor could have been used to shut off the collector pump earlier and save operating energy. The high limit should be a separate sensor from the present high limit protection sensor and the cut off should be set lower than the present high limit protection so that the system has over temperature protection.

- A complex control subsystem should be avoided. The complex control system resulted in operator errors and system malfunctions with resulting reduced performance.

- This solar system should be considered as a prototype system. A manufacturer who specialized in this type of solar system application could improve performance and reduce system cost after several replications of similar systems.

- Thermosiphoning or uncontrolled energy transfers particularly to the collectors, as in this case, can cause large storage losses. This loss mechanism caused abount one quarter the losses of all other storage loss mechanisms.

- The flush through or drainout freeze protection method is not as reliable as an antifreeze or drainback freeze protection scheme.

- The load side recirculation system caused losses which were equivalent to 10% or more of system loads. This pump could be shut off during times of no use or just shut off totally.

- The 3 way load side valve may be expensive window dressing which added little to system performance. If load side recirculation is deemed necessary and used with a timer, then probably routing through the solar storage tank is best. If load side recirculation will be pumped continuously, then perhaps routing through the auxiliary tank only is best.

- Simply resetting the tempering valve from 160° F to 122°F reduced the load side recirculation losses by about 50%. Solar energy use was also increased.

- The hot water loads are fairly constant from day to day. The hourly loads have distinct morning and evening peaks. The monthly loads vary according to the number of students, ground water temperature and hot water temperature.

- Since the daily loads are fairly constant for this application, future systems should consider an in-line boiler with practically no auxiliary storage tank.

- The ASHRAE Handbook value for maximum hourly gallons of hot water used per student is nearly twice the peak measured hourly rate.

- This solar collector system performed at the ASHRAE single panel test level.

- The roof mounting of the collector system appears to reduce collector energy losses and structural costs.

B. CONCLUSIONS

The Tucson Job Corps Center solar system performed very well although there were numerous control problems. The collector subsystem performed consistently at or above the ASHRAE test curve. The percent of incident solar energy delivered to load was 28% which was almost twice the NSDN average. Collector COP was 42 versus the NSDN average of 29. The solar energy delivered to the load per square foot of collector per day was 544 BTU/ft^2-day. This was 2-1/2 times the average NSDN solar system and somewhat better than a good NSDN system.

Storage tank performance was below average compared to NSDN and other SFBP sites. The loss rate of 0.76 BTU/ft^2-hr. is really quite high for 4" of sprayed foam. One improvement that could be made is to insulate the presently uninsulated tank head which is enclosed by the tank skirt. The storage tank performed better when it was stratified. Storage stratification, which occurred when the collector and load side recirculation pumps were off was enhanced by the cold supply water entry pipe configuration. Storage stratification was beneficial in reducing storage losses because of the uninsulated tank head.

The theoretical storage heat loss coefficient was 0.18 $BTU/hr\text{-}°ft^2$. The difference between the measured and theoretical heat loss coefficient is partially due to thermosiphoning between the storage tank and the collector array. This difference is equivalent to 2.4 million BTU per month until June when the tempering valve was reset.

The control subsystem performed very poorly due to bad wiring, unnecessary complexity, operator misinformation and lack of documentation. The necessity for two collector pumps and attendant controls is not justified. The fact that the system operators were unable to properly change or make control adjustments indicates a lack of training or proper documentation. More complete control documentation and operator training is required to avoid collector pump run on and perhaps collector freeze ups. The design failsafe freeze protection method should be implemented to assure that the freeze protection mode will work when required. Reliance on circulation of water by the collector pump is too risky. Some reduction in summer pumping costs seems possible if a high temperature limit switch were added to the storage tank to keep it below 170°F. A storage temperature of 170°F should be sufficient to carry the load. The high temperature limit switch would shutdown the collector pump earlier than the temperature differential controller.

F-Chart modeled solar energy delivered to the load for this system quite well, but it under-predicted the solar energy used. The problem that F-chart has with underpredicting system losses was overcome by increasing the auxiliary storage tank UA to account for the average monthly losses in the load side recirculation loop and boiler subsystems.

C. RECOMMENDATIONS

The recommendations sections is divided into two parts. Part I are recommendations for retrofits to the existing solar system. These are believed to be relatively simple, low-cost changes which will improve performance. Part II contains suggestions for design improvements on new systems. These could be retrofitted to the existing solar system but are expected to be quite costly and therefore not cost effective.

Part I

- o The storage tank head and manway cover should be insulated. Also, blocking the holes in the tank skirt will further reduce the skirt heat losses. This should reduce the storage heat loss coefficient to about 0.05 BTU/hr-°F-ft^2.
- o Continue the practice of shutting down the auxiliary boiler in summer. This shutdown time could be moved into mid May without any adverse effect on hot water temperature.
- o The load side pump should be turned off or placed on a timer. Since the pump was not always operational during the monitoring period and there were no complaints about hot water, the pump can be turned off with the expectation of no future complaints.
- o A short operator training course should be provided. The course should include familiarization with all modes of control operation and with routine maintenance procedures. Additionally, a checklist of control faults and possible causes should be posted near the controller.
- o Since the thermosiphoning losses from storage are so large, check valves should be installed in both collector supply and return lines. This should also be considered as good design/installation practice. The amount of spring tension should be determined so that the thermosiphoning head can be overcome while not adding excessive head to pump against.
- o Repair the drainout valve and return that mode to the controller.

Part II

- Replace the drainout freeze protection with a drainback or antifreeze system. The drainback freeze protection is preferred as being lower cost and more reliable.

- If some other mode of freeze protection is used besides recirculation and drains, then only one collector pump is needed. The performance gained by having a backup collector pump is not enough to merit the expense and complexity of two pumps.

Section IX

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APPENDIX A

PERFORMANCE FACTORS AND SOLAR TERMS

APPENDIX A

PERFORMANCE FACTORS AND SOLAR TERMS

The performance factors identified in the site equations (Appendix B) by the use of acronyms or symbols are defined in this appendix. Section A-1 describes general acronyms and letter designations used in this report. Section A-2 includes the acronym, the actual name of the performance factor, and a short definition.

Section A-1. General Acronyms

Section A-2. Performance Factor Definitions and Acronyms

APPENDIX A-1

GENERAL ACRONYMS

SECTION A-1

GENERAL ACRONYMS

A	When used as a prefix indicates a secondary subsystem (i.e ATST indicates the temperature of an auxiliary storage tank).
ABS	Absolute value
ATCE	Auxiliary Thermodynamic Conversion Equipment
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineering
AV or AVE	Used as a suffix to an acronym to indicate average value.
Btu	British thermal unit, a measure of heat energy. The quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit. One Btu is equivalent to 2.928 x 10^{-4} kWh of electrical energy.
C or CP	Specific Heat (BTU/lb -°F)
COP	Coefficient of Performance. The ratio of total usable energy delivered to a load to the operating energy necessary to transport the energy to that load.
D	Direction or position
DS	Discrete switch
DHW	Domestic hot water
E	When used in uncertainty calculations indicates the energy flow equation associated with that specific measurement.
ECSS	Energy Collection and Storage System
EE	Electric energy
EP	Electric power
ET	Elapse time (minutes)
F	Fuel flow rate (gal/min)
H	Enthalpy (Btu/lb-°F)
HR	Humidity

HW or HWS	Domestic or service hot water subsystem
HWD	Functional procedure to calculate the enthalpy change of water at the average of the inlet and outlet temperatures
kWh	Kilowatt hours, a measure of electrical energy. The product of kilowatts of electrical power applied to a load times the hours it is applied. One kWh is equivalent to 3,413 Btu of heat energy.
M	Mass flow rate (lb/min)
MAX	Used as a suffix to other acronyms to indicate the maximum value of the performance factors.
MIN	Used as a suffix to other acronyms to indicate the minimum value of the performance factor.
N	Performance parameter or number of terms.
NSDN	National Solar Data Network
P	Pressure (psi)
PD	Differential pressure (psi)
Q	Thermal energy (BTU)
RHO	Density (lbs/gal)
SCS	Space cooling subsystem
SERI	Solar Energy Research Institute
SH or SHS	Space heating subsystem
SOLMET	Solar radiation/meteorology data
T	Temperature (°F)
TCE	Thermodynamic conversion equipment
TD	Differential temperature (°F)
$\Delta\tau$	Time interval (min)
UA	Heat loss rate (BTU/°F)
V	Velocity (ft/sec)
W	Heat transport medium volume flow rate (gal/min)

X — When used in uncertainty calculations indicates the individual sensor measurements.

_P — Appended to a function designator to signify the value of the function during the previous iteration.

APPENDIX A-2

PERFORMANCE FACTOR
DEFINITIONS AND ACRONYMS

SECTION A-2

PERFORMANCE FACTOR DEFINITIONS AND ACRONYMS

ACRONYM	NAME	DEFINITION
ALTLLOSCOL	Calculated Collector Inlet Pipe Losses	The calculated energy losses from the primary pipes between the storage tank and the collector array based on measured temperatures and theoretical insulation values.
ALTLLOSSTO	Calculated Collector Outlet Pipe Losses	The calculated energy losses from the primary pipes between the collector array and the storage tank based on measured temperatures and theoretical insulation values.
ASTECH	Change in Energy Stored in Auxiliary Storage	Change in stored energy in auxiliary storage during specific time period.
ASTEFF	Auxiliary Storage Efficiency	Ratio of the sum of energy supplied to auxiliary storage and the change in auxiliary storage energy to the energy removed from auxiliary storage.
ASTEI	Energy Delivered to Auxiliary Storage	Amount of energy delivered to auxiliary Storage from the load.
ASTEO	Energy from Auxiliary Storage	Amount of energy removed from auxiliary storage by the chiller.
ASTLOSS	Auxiliary Storage Loss	Total energy losses from the auxiliary storage subsystem.
ASTOCAP	Auxiliary Storage Capacity	The volumetric storage capacity of the auxiliary storage tank.
ATCECOP	Auxiliary Cooling Subsystem Coefficient of Performance	The ratio of the auxiliary cooling subsystem load to thermal or electrical energy input.
ATCEI	Auxiliary Cooling Subsystem Thermal Energy Input	Equivalent thermal energy supplied as a fuel source to the auxiliary thermodynamic conversion equipment.

ACRONYM	NAME	DEFINITION
ATCEL	Auxiliary Cooling Load	Thermal energy removed from the air being cooled by the auxiliary thermodynamic conversion equipment.
ATCEOPE	Auxiliary Thermodynamic Conversion Equipment Operating Energy	Energy required to support the operation of the auxiliary thermodynamic conversion equipment; e.g., pumps, fans, etc.
ATCERJE	Auxiliary Rejected Energy	Amount of energy intentionally rejected from thermodynamic conversion equipment as a by-product of its operation.
ATST	Average Auxiliary Temperature	Average temperature of the auxiliary storage medium.
AXE	Auxiliary Electric Fuel Energy to Load Subsystem	Amount of electrical energy required as a fuel source for all load subsystems.
AXF	Auxiliary Fossil Fuel Energy to Load Subsystem	Amount of fossil energy required as a fuel source for all load subsystems.
AXT	Auxiliary Thermal Energy to Load Subsystem	Thermal energy delivered to all load subsystems to support a portion of the subsystem loads, from all auxiliary sources.
BL	Building Load	Sum of heat conducted through the building walls and ceilings, and heat convected through cracks, doors, and windows as air infiltration.
CAE	SCS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SCS to be converted and applied to the SCS load.
CAF	SCS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SCS to be converted and applied to the SCS load.
CAREF	Collector Array Efficiency	Ratio of the collected solar energy to the incident solar energy.

ACRONYM	NAME	DEFINITION
CAT	SCS Auxiliary Thermal Energy	Amount of thermal energy supplied to the SCS by the auxiliary equipment. For vapor compression units, it is CAE multiplied by compressor efficiency.
CDD	Cooling Degree-Days	A rough measure of the cooling requirement. This performance factor is the difference between the mean daily temperature, TAVE, and 65°F. If the mean is 65°F or less, cooling degree-days are zero.
CDE	Controlled Delivered Energy	Space heating intentionally delivered by the space heating subsystem including solar and auxiliary. This does not include heat losses from electric motors, pipes, storage, and other equipment.
CL	Space Cooling Subsystem Load	Energy required to satisfy the temperature control demands of the space cooling subsystem.
CLAREA	Collector Array Area	The gross area of one collector panel multiplied by the number of panels in the array.
CLECH	Collector Array Heat Capacity	The heat capacity of the fluid in the collector array.
CLEF	Collection Subsystem Efficiency	Ratio of the energy collected to the total energy incident on the collector array.
CLEFOP	Operational Collection Subsystem Efficiency	Efficiency when there is fluid in the collector loop.
CLS	Solar Energy Contribution to Cooling Load	The portion of the total cooling load which was satisfied by solar energy.
COLCAP	Collector Capacity	The volumetric fluid capacity of the collector array.

ACRONYM	NAME	DEFINITION
COPE	SCS Operating Energy	Amount of electrical energy required to support the SCS operation (fans and pumps) which is not intended to directly affect the thermal state of the subsystem.
COPE1	Solar-Unique Operating Energy	The operating energy necessary to the functioning of the solar energy portions of the SCS.
CSAUX	Auxiliary Energy to ECSS	Amount of auxiliary energy supplied to the ECSS.
CSCEF	ECSS Solar Conversion Efficiency	Ratio of the solar energy supplied from the ECSS to the load subsystems to the incident solar energy on the collector array.
CSE	Solar Energy to SCS	Amount of solar energy delivered to the SCS.
CSEO	Energy Delivered from ECSS to Load Subsytems	Amount of energy supplied from the ECSS to the load subsystems (including any auxiliary energy supplied to the ECSS).
CSFR	SCS Solar Fraction	Percentage of the SCS load which is supported by solar energy.
CSOPE	ECSS Operating Energy	Amount of energy used to support the ECSS operation (e.g., fans, pumps, etc.) which is not intended to affect directly the thermal state of the subsystem.
CSRJE	ECSS Rejected Energy	Amount of energy intentionally rejected or dumped from the ECSS subsystem.
CSVE	SCS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SCS and the actual electrical energy required to support the SCS, for identical SCS loads.

ACRONYM	NAME	DEFINITION
CSVF	SCS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SCS and the actual fossil energy required to support the SCS, for identical SCS loads.
EHL	Equipment Heating Load	Amount of energy supplied to the space heating subsystem equipment: solar, auxiliary thermal, operating energy converted to heat, and losses from the space heating equipment which contribute to heating (the building heating load less internal gains).
FANPWR	One-Time Measured Fan Power	Electrical energy used to run an air handler or fan coil. The quantity is calculated from a one-time measurement of volts times amps.
FEFF	Furnace Efficiency	Furnace or boiler efficiency. The value of 60% is used as a default value.
HAE	SHS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SHS to be converted and applied to the SHS load.
HAF	SHS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SHS to be converted and applied to the SHS load.
HAT	SHS Auxiliary Thermal Energy	Amount of thermal energy provided to the SHS by the auxiliary SHS.
HDD	Heating Degree-Days	A rough measure of the heating requirement. This performance factor is the difference between the mean daily temperature and 65°F. The mean is the average of the minimum and maximum tempera tures for a given day. If the mean is 65°F or more, heating degree-days are zero.
HOPE	SHS Operating Energy	Amount of energy required to support the SHS operation (which is not intended to be applied directly to the SHS load).

ACRONYM	NAME	DEFINITION
HOPE 1	Solar-Unique SHS Operating Energy	Operating energy used to deliver solar energy to the space heating subsystem.
HSE	Solar Energy to SHS	Amount of solar energy delivered to the SHS, including thermal losses from solar heated fluids.
HSEL	Solar Energy Losses to SHS	Solar energy losses from storage and other equipment which heat the conditioned space.
HSEM	Measured Solar Energy to SHS	Solar energy intentionally delivered to SHS by the distribution network. Does not include solar energy losses which also sometimes contribute to space heating.
HSFR	SHS Solar Fraction	Percentage of the SHS load which is supported by solar energy.
HSVE	SHS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SHS and the actual electrical energy required to support the solar SHS, for identical SHS loads.
HSVF	SHS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SHS and the actual fossil energy required to support the SHS, for identical SHS loads.
HWAE	HWS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the HWS to be converted and applied to the HWS load.
HWAF	HWS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the HWS to be converted and applied to the HWS load.
HWAT	HWS Auxiliary Thermal Energy	Amount of energy provided to the HWS by a heat transfer fluid from an auxiliary source.
HWCSM	Service Hot Water Consumed	Amount of heated water delivered to the load from the HWS excluding tempering water.

ACRONYM	NAME	DEFINITION
HWCSMA	Tempered Hot Water Consumed	Amount of heated water delivered to the load from the HWS including tempering water.
HWDM	Hot Water Demand	Total energy required to raise the hot water used from the supply water temperature to the hot water temperature.
HWDSFR	HWS Solar Fraction of Demand	Percentage of the "hot water demand" which is supplied by solar energy.
HWL	Hot Water Subsystem Load	Amount of energy supplied to the HWS.
HWOPE	HWS Operating Energy	Amount of energy required to support the HWS operation which is not intended to be applied directly to the HWS load.
HWOPE1	Solar-Unique HWS Operating Energy	Operating energy necessary to deliver solar energy to the DHW subsystem.
HWSE	Solar Energy to HWS	Amount of solar energy delivered to the HWS.
HWSE1	Solar Energy to Preheat Tank	The amount of solar energy input to a preheat tank.
HWSFR	HWS Solar Fraction	Percentage of the HWS load which is supported by solar energy.
HWSVE	HWS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional HWS and the actual electrical energy required to support the HWS, for identical HWS loads.
HWSVF	HWS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional HWS and the actual fossil energy required to support the HWS, for identical loads.

ACRONYM	NAME	DEFINITION
HXEFF	Heat Exchanger Effectiveness	This nondimensional number indicates the effectiveness of the heat exchanger as a ratio of the rate of energy transfer to the difference in temperature between the fluids on both sides of the heat exchanger.
LINLOS	Recirculation Loop Losses	Thermal energy losses due to recirculation of hot water in a large building loop.
LINLOSCOL	Measured Collector Inlet Pipe Losses	The measured energy losses from the primary pipes between the storage tank and the collector array.
LINLOSSTO	Measured Collector Outlet Pipe Losses	The measured energy losses from the primary pipes between the collector array and the storage tank.
OPPNT	Operating Point	The collector inlet temperature minus the outdoor temperature divided by the insolation while the collectors are operating.
PRELOS	Preheat Tank Losses	The difference between the input solar energy to a preheat tank and the output solar energy to the HWS tank. This includes losses and changes in internal energy.
PUMPWR	One-Time Measured Pump Power	Electrical energy used to run a pump. The quantity is calculated from a one-time measurement of volts times amps.
SE	Incident Solar Energy	Amount of solar energy incident upon one square foot of the collector plane per day.
SEA	Incident Solar Energy on Array	Amount of solar energy incident upon the collector array.
SEC	Collector Solar Energy	Amount of thermal energy added to the heat transfer fluid for each square foot of the collector area.

ACRONYM	NAME	DEFINITION
SECA	Collected Solar Energy by Array	Amount of thermal energy added to the heat transfer fluid by the collector array.
SEL	Solar Energy to Load Subsystems	Amount of solar energy supplied by the ECSS to all load subsystems.
SEOP	Operational Incident Solar Energy	Amount of solar energy incident upon the collector array when the collector loop is active.
SFR	Solar Fraction of System Load	Percentage of the system load which was supported by solar energy.
SSSR	System Solar Savings Ratio	The ratio of the sum of the solar contributions to the system load minus the solar-unique system operating energy to the total system load.
STECH	Change in ECSS Stored Energy	Change in ECSS stored energy during specific time period.
STEFF	ECSS Storage Efficiency	Ratio of the sum of energy supplied by ECSS storage and the change in ECSS stored energy to the energy delivered to the ECSS storage.
STEI	Energy Delivered to ECSS Storage	Amount of energy delivered to ECSS storage by the collector array and from auxiliary sources.
STEO	Energy Supplied by ECSS Storage	Amount of energy supplied by ECSS storage to the load subsystems.
STLOSS	Storage Loss	Total energy losses from the storage subsystem.
STOCAP	Storage Capacity	The volumetric storage capacity of the storage subsystem.

ACRONYM	NAME	DEFINITION
STPER	Effective Heat Transfer Coefficient	The overall heat transfer coefficient for the hot solar storage tank as measured for the month: ratio of storage loss to product of outside tank area, average temperature difference across insulation, and number of hours in the month.
SUR-AREA	Surface Area	The storage tank surface area.
SYSCOP	System Coefficient of Performance	The ratio of the total solar energy delivered to the load to the sum of the solar operating energies.
SYSL	System Load	Energy required to satisfy all desired temperature control demands at the output of all subsystems.
SYSOPE	System Operating Energy	Amount of energy required to support the system operation, including all subsystems, which is not intended to be applied directly to the system load.
SYSOPE1	Solar-Unique Operating Energy	Operating energy that is used specifically for the solar components of the system.
SYSPF	System Performance Factor	Ratio of the system load to the total equivalent fossil energy expended or required to support the system load.
TA	Ambient Temperature	Average temperature of the ambient air.
TANKV	HWS Heat-up Energy	The energy required to heat all the water in the HWS tank from the cold water supply temperature to the hot water outlet temperature.
TAVE	Average Daily Temperature	The average daily temperature as defined by the National Weather Service; i.e., the average of the minimum and maximum temperatures for a given day.

ACRONYM	NAME	DEFINITION
TB	Building Temperature	Average temperature of the air in the controlled space of the building.
TC	Concrete Temperature	The temperature of material adjacent to a pipe of a ground contact heat pump coil.
TCECOP	TCE Coefficient of Performance	Coefficient of performance of the thermodynamic conversion equipment, typically, the ratio of equipment load to thermal energy input.
TCEI	TCE Thermal Input Energy	Equivalent thermal energy which is supplied as a fuel source to thermodynamic conversion equipment.
TCEL	Thermodynamic Conversion Equipment Load	Controlled energy output of thermodynamic conversion equipment.
TCEOPE	TCE Operating Energy	Amount of energy required to support the operation of thermodynamic conversion equipment (e.g., pumps and fans).
TCERJE	TCE Reject Energy	Amount of energy intentionally rejected or dumped from thermodynamic conversion equipment as a by-product or consequence of its principal operation.
TCOL	Collector Temperature	The average temperature of the fluid in the collector array.
TDA	Daytime Average Ambient Temperature	Average temperature of the ambient air during the daytime (during normal collector operation period).
TECSM	Total Energy Consumed by System	Amount of energy demand of the system from external sources; sum of all fuels, operating energies, and collected solar energy.
THW	Service Hot Water Temperature	Average temperature of the service hot water supplied by the system.

ACRONYM	NAME	DEFINITION
TIN	Collector Inlet Temperature	The measured of the fluid at the inlet to the collector array.
TS	Soil Temperature	The temperature of soil near a ground contact heat pump coil.
TST	ECSS Storage Temperature	Average temperature of the ECSS storage medium.
TSVE	Total Electrical Energy Savings	Difference in the estimated electrical energy required to support an assumed similar conventional system and the actual electrical energy required to support the system, for identical loads; sum of electrical energy savings for all subsystems.
TSVF	Total Fossil Energy Savings	Difference in the estimated fossil energy required to support an assumed similar conventional system and the actual fossil energy required to support the system, for identical loads; sum of fossil energy savings of all subsystems.
TSW	Supply Water Temperature	Average temperature of the supply water to the hot water subsystem.

APPENDIX B

PERFORMANCE EQUATIONS

Apppendix B

PERFORMANCE FACTORS

I. CONVERSION OF RAW COUNTS TO ENGINEERING UNITS

Calculation of performance factors for a solar system involves several steps. Data from the individual sensors are converted to counts by the Site Data Acquisition System (SDAS). Raw count data is transmitted from the SDAS to a System 7 computer located at the Vitro facility in Silver Spring, Maryland, where it is stored on magnetic tape.

The raw count data is transferred to the main frame computer where it is converted to engineering units using the following equations, depending on the type of sensor.

L: Engineering Units $= a_0 + (a_1 \times \text{counts})$

T: Engineering Units $= a_0 + (a_1 \times \text{counts}) + (a_2 \times \text{counts}^2) + (a_3 \times \text{counts}^3)$

DS: Engineering Units $= 1$ if $a_0 \leq \text{counts} \leq a_1$

$= 0$ if otherwise

G: Engineering Units $= a_1 \times \sqrt{\text{counts}}$

a_0, a_1, a_2, a_3 are calibration constants determined from both factory and on-site calibration checks. These constants are listed for each sensor in the Instrumentation Program and Components List (IPCL) for each site (Reference 1).

The L (linear conversion) equation is used for electric power (EP), insolation (I), elapse timers (EP) and totalizers (WT or F).

The T (third order) conversion equation is used for temperature sensors.

The DS logic conversion is used for yes or no situations to indicate if a switch is on or off.

Conversion type G is the general Ramapo equation, which is used for Ramapo flowmeters (W).

II. SCAN-LEVEL PERFORMANCE FACTOR CALCULATIONS

The engineering unit values used in the equations are given in Sections VI and VII in this Appendix to calculate system performance factors. There are two groups of equations: scan-level and hourly. The scan level equations calculate performance factors for hourly intervals and can be in one of three forms depending on the source of the measurement data used.

1. Average value

Values such as temperatures are reported as the average value over the time interval. For example, the scan-level equation for the ambient temperature (TA) averaged over the hour is written like this.

$$TA = \Sigma\, T001 \times \Delta\tau \times (1/60)$$

where this equation actually represents the following calculation.

$$TA = \frac{\sum_{\tau=1}^{11.25} T001 \times \Delta\tau}{\sum_{\tau=1}^{11.25} \Delta\tau}$$

where T001 the temperature measurement in (^{o}F) made at each scan interval during the hour.

$\Delta\tau$ is the scan interval in minutes (5.33).

2. Rate measurements

Flowmeters (W), pyranometers (I) and power meters (EP) measure rates. (The SDAS makes ten readings of these values each scan and averages them). Performance factors calculated using these measurements at the scan-level are integrated over the entire hour so that the performance factor units are in terms of the total quantity for that hour. For example, the scan-level equation for insolation (SE) would be BTU/ft^2-hr

$$SE = \sum_{\tau=1}^{11.25} I001 \times$$

where I001 is the measured level of insolation in BTU/ft^2-min.

$\Delta\tau$ is the scan interval in minutes (5.33).

3. Fuel consumption (F), water consumption (WT) and elapsed time (ET) are measured by totalizers. Therefore performance factors calculated using measurements from these devices are determined by summing the measurements made at each scan interval during the hour. For example, the hot water consumption (HWCSM) is calculated using the following scan-level equation:

$$HWCSM = \Sigma\, WT300$$

where WT300 is the measured hot water used during each scan interval in gallons.

For many calculations it is necessary to convert volumetric flow and flow rates to mass flow which has been corrected for temperature effects. For convenience the measurements of both flow rate and totalizing meters are converted to units of pounds/minute. (See the system schematic in section II of the report for identification of the type of flow sensor which was used for each measurement.) In the following equations, Section VI, if the sensor value has been converted to mass flow the letter designation for the sensor reading is changed from a W or WT to M.

To make it easier to locate sensors on the schematic and to read the equations, a sensor numbering scheme has been developed which designates a range of numbers to be used for each subsystem. This numbering scheme is presented in Table B-1. Constant values from one time measurement, such as pump power consumption are given the same number as the associated elapse timer. For example, collector pump operating energy would be calculated as follows:

$$CSOPE = \Sigma\ 56.8833 \times EP100 \times ET100$$

where 56.8833 is the conversion factor BTU/KW-min.

EP100 is a one time measurement of pump power requirements in KW.

ET100 is the measured elapsed time that the pump was on during that scan interval.

Table B-1. SENSOR NUMBERING SCHEME

Subsystem Designations Number Sequence	Subsystem/Data Group
001 to 099	Climatological
100 to 199	Collector and Heat Transport
200 to 299	Thermal Storage
300 to 399	Hot Water
400 to 499	Space Heating
500 to 599	Space Cooling
600 to 699	Building/Load

There are several subroutines in the computer code which the analyst can use by simply calling them out in the site specific equations. These include the routines used to convert volumetric flow to mass flow as discussed above and the two used to calculate energy flow from mass flow and temperature values. When the fluid is water, the HWD subroutine is used. For example, collector solar energy (SECA) is calculated as follows:

$$SECA = \sum_{\tau=1}^{11.25} M100 \times HWD\ (T150,\ T100) \times \Delta\tau$$

where M100 is the mass flow of water in the collector loop in lb/min

HWD calculates the enthalpy change in the water for a temperature change from temperature T100 to T150. (The value produced by HWD is in BTU/lb_m for the given temperature difference.)

The HWD function finds the specific heat of water at the average of the inlet and outlet temperatures given as arguments of the function. The function also finds the temperature difference between the inlet and outlet temperatues. If a fluid other than water is used, then a function like CPP25W( ) is used to find the average specific heat, in BTU/lb_m-^{o}F, of the heat transfer fluid. For example, SECA would be calculated as follows:

$$SECA = \sum_{\tau=1}^{11.25} M100 \times CPP25W[(T150 + T100)/2] \times (T150 - T100) \times \Delta\tau$$

The CPP25W identifies the collector fluid as a 25% solution of propylene-glycol by weight. The units of the CP function are BTU/lb_m^{o}F, for a fluid with an average temperature of (T150+T100)/2.

Finally, it should be noted, that at the analyst's discretion, special site specific equations may be added to the computer code. The equations of this type in Section VI and VII of this Appendix are marked with an asterisk. These acronyms are not included in Appendix A but the headings are self explanatory.

III. HOURLY-LEVEL PERFORMANCE FACTOR CALCULATIONS

Some performance factors are calculated at the hourly level rather than the scan level. Equations for these performance factors are presented in Section VII of this appendix. Input parameters for these equations are either the average or summations from the scan-level equations.

The Change in Storage Energy (STECH) is unique in that rather than using values from the scan-level equations, this calculation is based on the first and last measured value for the time interval being evaluated (hour, day or month).

IV. INTEGRATION AND PERFORMANCE FACTOR INTERPOLATION

Solar system data is provided on a whole hour, whole day and whole month basis. Thus performance factors are computed for periods of 60 minutes (beginning and ending on the hours), for each calendar day of 24 hours, and or each calendar month (28, 29, 30 or 31 days). The sampled measurement data is integrated over the specified time periods, and interpolation is used to estimate the value of missing or invalid measurement data.

Integration is the process used for building hourly performance factors from measurement data taken every 320 seconds (scan level). The integration is considered normal if no measurement values are missing at the scan level within an hour. If one or more values are missing interpolation is used to fill in the data gaps.

A. Normal Integration

This integration, over time, uses a rectangular scheme in which it is assumed that the present measurement sample value is valid across the entire time interval since the previous measurement sample was taken. The following figure illustrates normal integration:

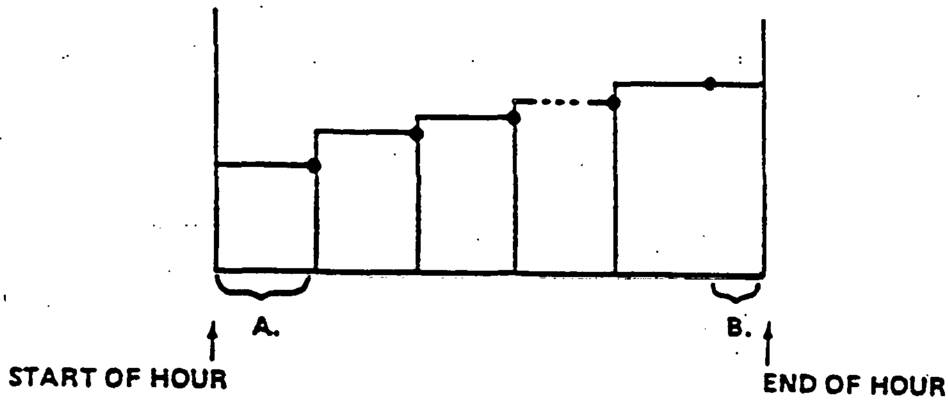


Figure 1

To simplify this illustration, only five sample points were shown. In practice, either eleven or twelve samples will be taken within an hour, depending on timing.

For the first time interval in the hour before the first scan time (a), the value at the first scan time is used. For all time intervals until the end of the hour, the present sample value is used across the elapsed time interval from the previous sample time. For the last time interval in the hour (b), after the last scan time but before the end of the hour, the value at the last scan time in the hour is used. The following ramifications help to clarify the results of integration.

1. Within any hour, only measurement sample values from that hour are used in integration. Sample values from previous hours are not considered.

2. The rectangular integration biases the integrated value high when the measurement values are ascending and low when they are descending.

3. Normal integration is performed only for the ideal case, with no missing data values.

4. Scan level performance factors are integrated to obtain performance factors at the end of each hour. The scan level values can be simply measurements from a single sensor as in the case of ambient temperature but are usually performance factors computed using measured data from several sensors. When several measurements are involved, loss of any one measurement prevents calculation of the performance factor for that scan. Lost scan data values are interpolated.

5. The impact of interpolation error on the performance factors is relatively small compared with other sources of uncertainty. Performance factor accuracy is affected by imperfections in instrumentation, signal conditioning and computer data processing.

B. Interpolation of Scan Level Performance Factors to Provide Hourly Level Factors

The objective of the interpolation process is to estimate all performance factors that are missing and relevant.

Lost scan level performance factors are assigned values through the rectangular integration scheme. The computational technique is similar to that used for normal integration.

The difference is that the time interval between scans is longer. The following figure illustrates this interpolation. The X indicates the lost scan level performance factors. The area under the solid line represents the true integration of the performance factor. The area between the dashed and solid lines represents the error due to interpolation.

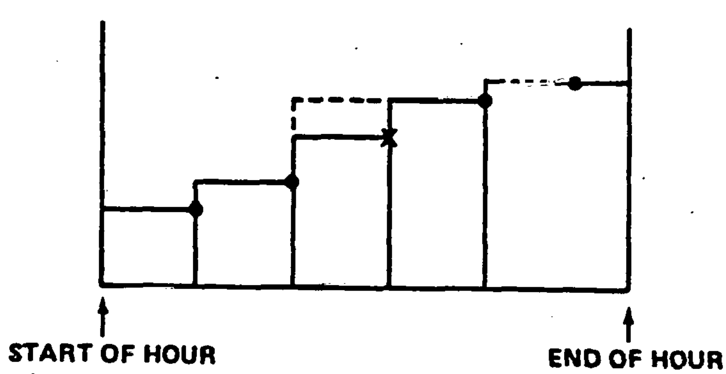


Figure 2

If two consecutive data points are missing, the value is interpolated as indicated by the dashed line in the following figure:

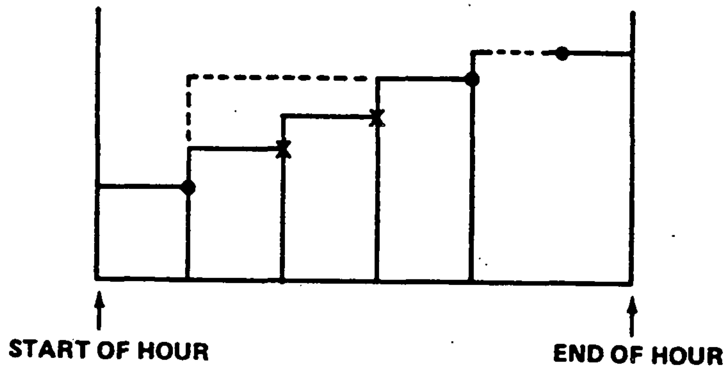


Figure 3

Measurements from the previous hour do not affect interpolating for the current hour. This figure shows what occurs at the start of an hour:

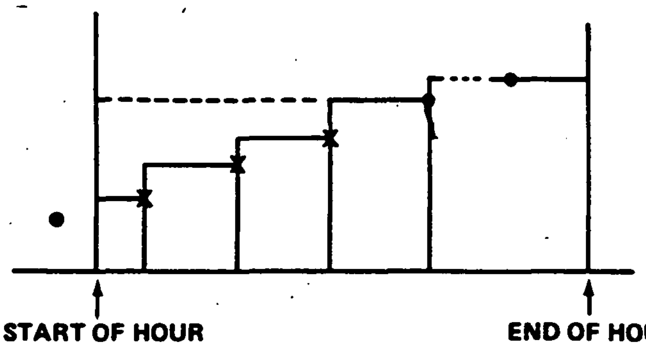


Figure 4

A minimum of 4 scans of data per hour are required to compute an hourly performance factor. With no data gaps, either 11 or 12 measurement scans are made within an hour, depending on timing. Thus, as many as eight missing data points can be interpolated in an hour. When there are three or less scans available in an hour, they are discarded and the performance factor is assigned an interpolated value as discussed in the following paragraph.

C. Interpolation of Unavailable Hourly Level Performance Factors

Hourly level performance factors that are invalid, i.e., have a default value of $-1x10^{-15}$ indicating lost data, receive a value which has been interpolated from measured data. If no valid measured data is available, a zero value is assigned. If a performance factor is "Not Applicable," it is not processed. Interpolation is executed according to the following flowchart.

The flowchart provides for these rules:

1. Interpolated values are always based on measured performance factors; never on interpolated factors.

2. Interpolated values are only used for scan and hourly level performance factors so a consistent set of sensor data and performance factor definitions are used.

3. Interpolated values are not assigned to whole days because there are no typical or average days, only irregularly varying days. A whole day can be interpolated, however, it is performed one hour at a time if there are measured performance factors to support each hour on other days.

4. Interpolated performance factors (I) should be as near in time as possible to the missing performance factor. The order of preference:

   a. I = (PFPH + PFFH)/2 where PFPH is the nearest measured hourly value of the factor within three hours previous to the missing value; PFFH is the nearest measured hourly value of the factor within three hours following the missing value.

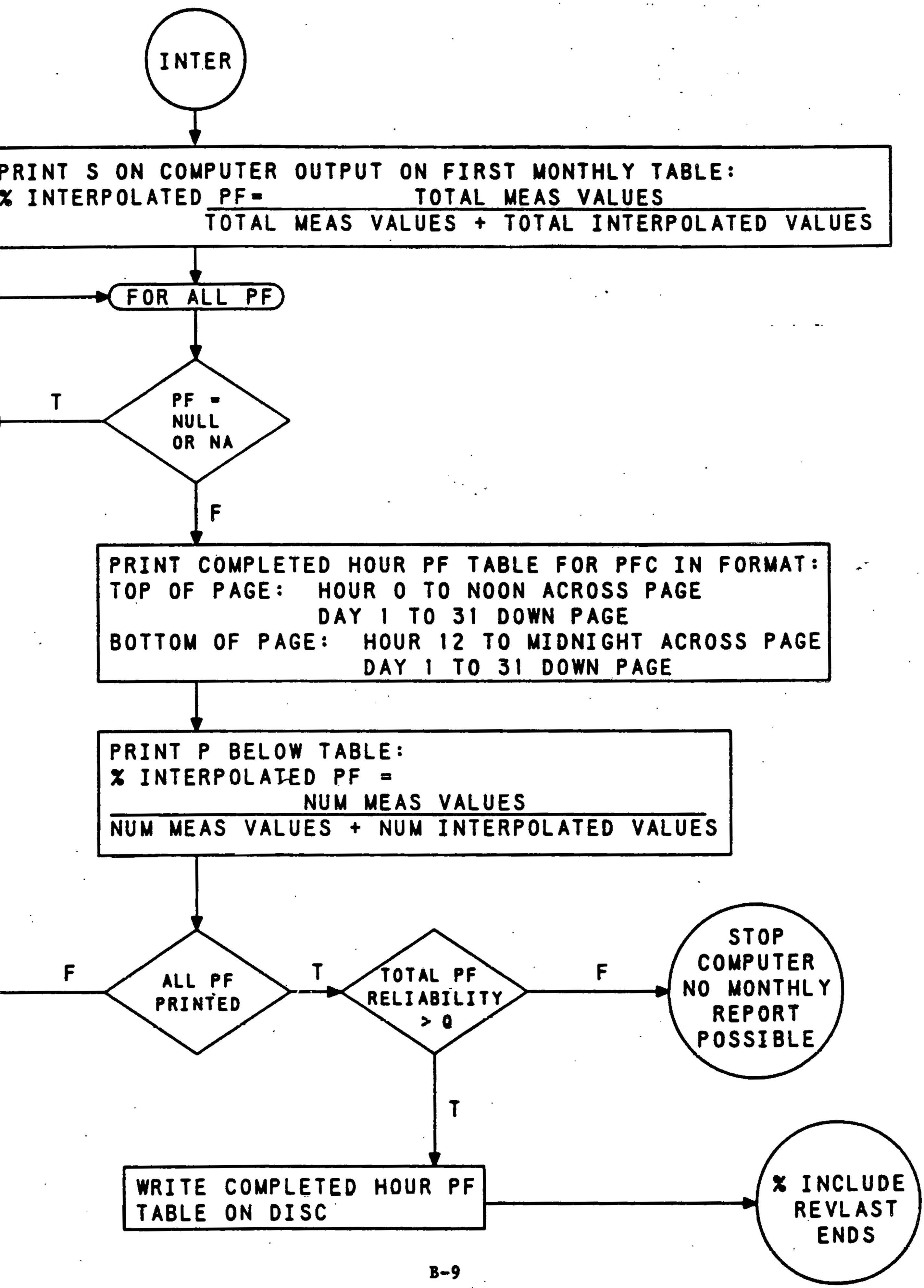
   b. I = PFPH (when no measured values available for PFFH).

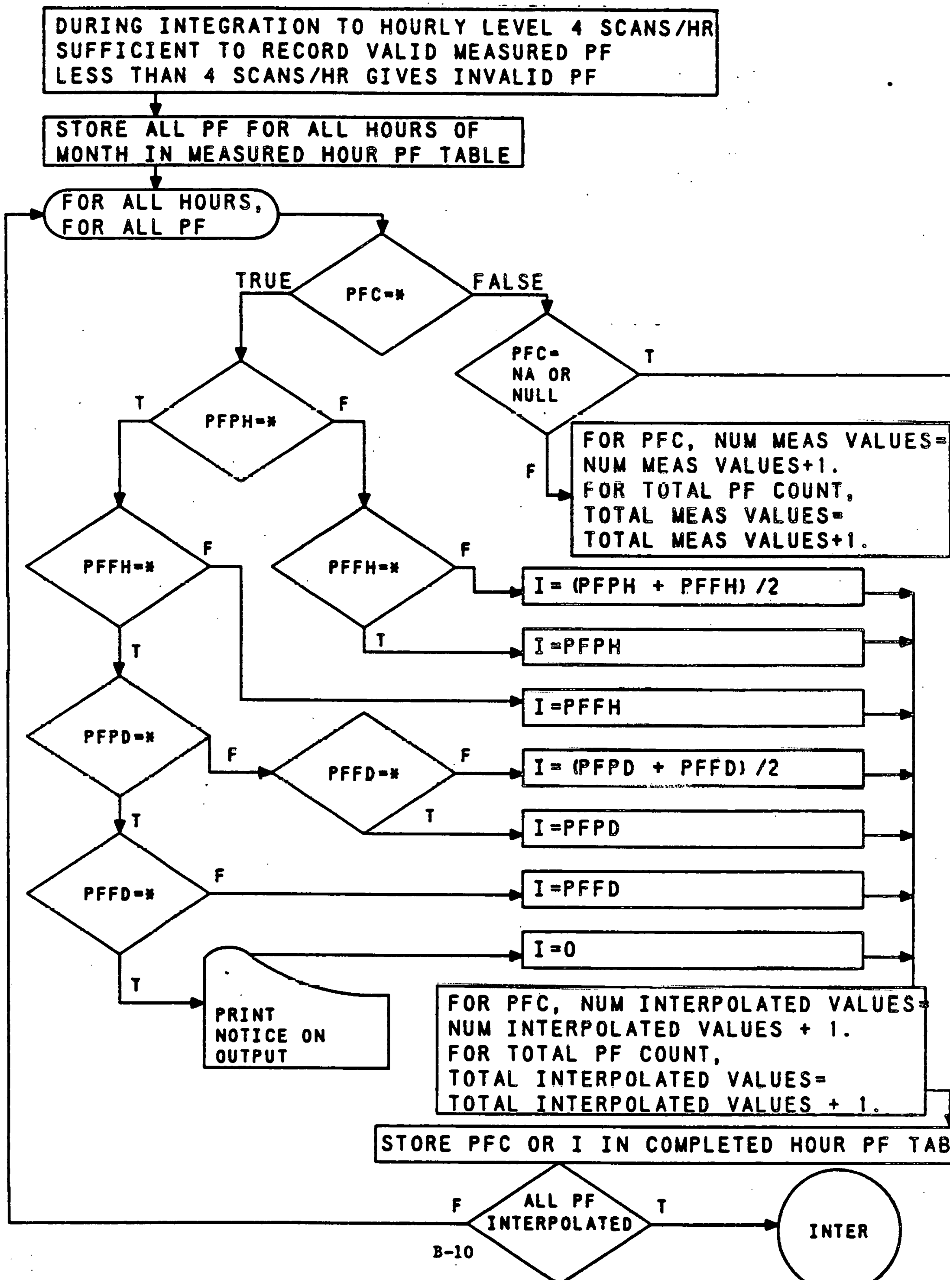
   c. I = PFFH (when no measured values available for PFPH).

   d. I = (PFPD + PFFD)/2 where PFPD is a measured value of the factor during the same hour of the day on the closest previous day in the month; PFFD is a measured value of the factor during the same hour of the day on the closest following day in the month.

   e. I = PFPD (when no measured values available for PFFD).

   f. I = PFFD (when no measured values available for PFPD).


INTER
PRINT S ON COMPUTER OUTPUT ON FIRST MONTHLY TABLE:
% INTERPOLATED PF= TOTAL MEAS VALUES / TOTAL MEAS VALUES + TOTAL INTERPOLATED VALUES
FOR ALL PF
T
PF = NULL OR NA
F
PRINT COMPLETED HOUR PF TABLE FOR PFC IN FORMAT:
TOP OF PAGE: HOUR 0 TO NOON ACROSS PAGE
DAY 1 TO 31 DOWN PAGE
BOTTOM OF PAGE: HOUR 12 TO MIDNIGHT ACROSS PAGE
DAY 1 TO 31 DOWN PAGE
PRINT P BELOW TABLE:
% INTERPOLATED PF = NUM MEAS VALUES / NUM MEAS VALUES + NUM INTERPOLATED VALUES
F
ALL PF PRINTED
T
TOTAL PF RELIABILITY > Q
F
STOP COMPUTER NO MONTHLY REPORT POSSIBLE
T
WRITE COMPLETED HOUR PF TABLE ON DISC
% INCLUDE REVLAST ENDS


DURING INTEGRATION TO HOURLY LEVEL 4 SCANS/HR SUFFICIENT TO RECORD VALID MEASURED PF LESS THAN 4 SCANS/HR GIVES INVALID PF
STORE ALL PF FOR ALL HOURS OF MONTH IN MEASURED HOUR PF TABLE
FOR ALL HOURS, FOR ALL PF
PFC=*
TRUE
FALSE
PFC= NA OR NULL
PFPH=*
FOR PFC, NUM MEAS VALUES= NUM MEAS VALUES+1. FOR TOTAL PF COUNT, TOTAL MEAS VALUES= TOTAL MEAS VALUES+1.
PFFH=*
I= (PFPH + PFFH) /2
I=PFPH
I=PFFH
PFPD=*
PFFD=*
I= (PFPD + PFFD) /2
I=PFPD
I=PFFD
I=0
PRINT NOTICE ON OUTPUT
FOR PFC, NUM INTERPOLATED VALUES= NUM INTERPOLATED VALUES + 1. FOR TOTAL PF COUNT, TOTAL INTERPOLATED VALUES= TOTAL INTERPOLATED VALUES + 1.
STORE PFC OR I IN COMPLETED HOUR PF TAB
ALL PF INTERPOLATED
INTER

5. Non-measured performance factor values are flagged. Interpolated values are marked with a "B" on the computer output. An "X" is noted by arbitrary zero values for which no relevant measured data is available for interpolation. A number, P, is printed with each monthly performance factor where $0 \leq P \leq 1.0$ and

$$P = \frac{\text{number of hours the factor is measured}}{\text{number of hours in the month}}$$

V. REFERENCE

1. Instrumentation Program and Components List (IP 320057) Rev. C for Tucson Job Corps Center, SFBP 1356, November 19, 1984.

VI. TUCSON JOB CORPS CENTER SCAN-LEVEL EQUATIONS

WEATHER

AMBIENT MINIMUM AND MAXIMUM TEMPERATURE (^{o}F)

TAMIN = MIN(TAMIN, T001)

TAMAX = MAX (TAMAX, T001)

AMBIENT TEMPERATURE (^{o}F)

$TA = \Sigma\, T001 \times \Delta\tau \times (1/60)$

DAYTIME AMBIENT TEMPERATURE ± 3 HOURS OF SOLAR NOON (^{o}F)

IF ABS(TIME_OF_DAY - TIME_OF_SOLAR_NOON) < 180

THEN $TDA = \Sigma\, T001 \times \Delta\tau \times (1/60)$

COLLECTOR

COLLECTOR INLET TEMPERATURE (^{o}F)

$TIN = \Sigma\, T100 \times \Delta\tau \times (1/60)$

INSOLATION (BTU/FT^2)

$SE = \Sigma\, I001 \times \Delta\tau$

INSOLATION DURING OPERATION OF COLLECTOR PUMP (BTU)

SEOP = Σ CLAREA x I001 x $\Delta\tau$

where: M100 > 0

CLAREA = 1,659 FT^2

SOLAR ENERGY COLLECTED (BTU)

SECA = Σ M100 x HWD (T150, T100) x $\Delta\tau$

COLLECTOR OPERATING ENERGY (BTU)

CSOPE = Σ (EP101 x ET101 + EP102 x ET102) x 56.8833

where: EP101 = 0.82 kW, EP102 = 0.82 kW (one time measurements)

56.8833 = BTU/kW-min

LINELOSS - COLLECTOR INLET PIPES (BTU)

LINLOSCOL = Σ M100 x HWD(T101, T100) x $\Delta\tau$

ALTLLOSCOL = Σ UACOL x (T101 - T001) x $\Delta\tau$ x (1/60)

where: UACOL = 12.0 BTU/hr°F (based on theoretical value for pipe insulation of measured thickness)

LINELOSS - COLLECTOR OUTLET PIPES (BTU)

LINLOSTO = Σ M100 x HWD(T150, T151) x $\Delta\tau$

ALTLLOSSTO = UASTO x (T151 - T001) x $\Delta\tau$ x (1/60)

where: UASTO = 11.9 BTU/hr°F (based on theoretical value for pipe insulation of measured thickness)

ENERGY REJECTED FOR FREEZE PROTECTION (BTU)

* FP_SECA = ABS(SECA)

IF DS801 = 'on' (freeze protection mode switch)

---

*Special equations developed for this system only.

DHW RECIRCULATION LOSSES (BTU)

* RECIRCLOS = Σ (M350 - M300) x HWD(T351, T370) x $\Delta\tau$
(Nov 1984 to May 1985)

if M350 - M300 > 0

* RECIRCLOS = Σ (M200 - M300) x HWD(T250, T200) (June & July 1985)

SOLAR MAKE UP OF DHW RECIRCULATION LOSSES (BTU)

* RECIRCSOL = Σ (M200 - M300) x HWD(T250, T200) x $\Delta\tau$

if M200 - M300 > 0

STORAGE

STORAGE TEMPERATURE (^{o}F)

TST1 = Σ (T201 + T202 + T203)/3 x $\Delta\tau$ x (1/60)

ALTERNATE STORAGE INLET ENERGY CALCULATION (BTU)

STEI = SECA - ALTLOSSTO x 2

where the multiplier of 2 is used to account for the difference between actual and theoretical pipe losses.

STORAGE ENERGY OUT (BTU)

November 1984 to March 1985:

STEO = Σ (M200 - M300) x HWD(T250, T370) +
M300 x HWD(T250, T300) x $\Delta\tau$

if M200 > M300

STEO = Σ M200 x HWD(T250, T300) x $\Delta\tau$

if M200 < M300

April to July 1985:

STEO = Σ M300 x HWD(T340, T300) x $\Delta\tau$
+ RECIRCLOS

*Special equation developed for this system only

DOMESTIC HOT WATER

SUPPLY WATER TEMPERATURE (^{o}F)

$$TSW = \Sigma\, T300 \times \Delta\tau \times (1/60)$$

(weighted by volume of water delivered)

HOT WATER TEMPERATURE (^{o}F)

$$THW = \Sigma\, T350 \times \Delta\tau \times (1/60)$$

(weighted by volume of water delivered)

HOT WATER CONSUMED (GALLONS)

$$HWCSM = \Sigma\, W300$$

HOT WATER DEMAND (BTU)

$$HWDM = \Sigma\ M300 \times HWD(T351, T300) \times \Delta\tau$$ (Nov 1984 to May 1985)

$$HWDM = \Sigma\ M300 \times HWD\ (T340, T300) \times \Delta\tau$$ (June & July 1985)

DHW RECIRCULATION PUMP OPERATING ENERGY (BTU)

* $HWOPEALT = \Sigma\, EP370 \times 56.8833 \times \Delta\tau$

if DS370 = 'ON'

where: EP370 = 0.512 kW (one time measurement)

56.8833 - BTU/kW-min

DHW BOILER CIRCULATION PUMP OPERATING ENERGY (BTU)

* $HWOPEAUX = \Sigma\, ET360 \times EP360 \times 56.8833$

if ET360M > 0.1

where: EP360 = 0.483 kW (one time measurement)

56.8833 = BTU/kW-min

HOT WATER OPERATING ENERGY (BTU)

$$HWOPE = HWOPEALT + HWOPEAUX$$

---

*Special equation developed for this system only.

DHW AUXILIARY THERMAL ENERGY (BTU)

$HWAT = \Sigma\ M350 \times HWD(T350, T340) \times \Delta\tau$

if $T340 < T350$

DHW AUXILIARY FOSSIL FUEL (BTU)

$HWAF = \Sigma\ F300 \times 1{,}021 \times \Delta\tau\ (1/60)$

where: $1{,}021 = BTU/ft^3$ of Natural Gas

PUMP RUN TIMES

COLLECTOR PUMP P1 (MINUTES)

* $P1\_RT = \Sigma\ ET101$

COLLECTOR PUMP P2 (MINUTES)

* $P2\_RT = \Sigma ET102$

AUXILIARY PUMP P3 (MINUTES)

* $P3\_RT = \Sigma\ ET360$

RECIRCULATION PUMP P4 (MINUTES)

* $P4\_RT = \Sigma\ DS370 \times \Delta\tau$

VII. HOURLY EQUATIONS

COLLECTOR

OPERATING POINT ($^{\circ}F\text{-}ft^2\text{-}hr/BTU$)

$OPPNT = (TIN - TA)/SE$

if $SE > 0$

SOLAR ENERGY ON THE ARRAY (BTU)

$SEA = CLAREA \times SE$

where: $CLAREA = 1{,}659\ ft^2$

*Special equations developed for this system only.

SOLAR ENERGY COLLECTED PER COLLECTOR SQUARE FOOT (BTU/ft^2)

SEC = SECA/CLAREA

where: CLAREA = 1,659 ft^2

COLLECTOR EFFICIENCY (%)

CLEF = SECA/SEA x 100

COLLECTOR OPERATIONAL EFFICIENCY (%)

CLEFOP = SECA/SEOP x 100

STORAGE

STORAGE ENERGY CHANGE (BTU)

STECH = STOCAP x [CP(TST1) x RHO(TST1) x TST1 - CP(TST_P) x RHO(TST_P) x TST_P]

where STOCAP = 2,200 gallons

TST1 is the average storage tank temperature at the end of the hour and TST_P is the average storage temperature at the end of the previous hour.

STORAGE EFFICIENCY (%)

STEFF = (STECH + STEO)/STEI x 100

if STEI > 0

STORAGE ENERGY LOSS (BTU)

STLOSS = STEI - STEO - STECH

APPARENT STORAGE INSULATION COEFFICIENT

STPER = STLOSS/[SUR-AREA x (TST - TA)]

where: SUR-AREA = 445 ft^2

*Special equations developed for this system only.

DOMESTIC HOT WATER

SOLAR ENERGY TO THE DHW SUBSYSTEM (BTU)

HWSE = STEO

AUXILIARY HOT WATER THERMAL ENERGY (BTU)

HWAT = HWAT

if Date > 12/1/84 and Date < 3/1/85 then HWAT = HWAT + 10,260

to adjust for boiler losses. (Measured during a period where

there was no solar contribution.)

AUXILIARY HOT WATER TANK ENERGY CAPACITY (BTU) (See definition Appendix A.2 and HWDSFR below)

TANKV = HWCAP x [RHO(THW) x CP(THW) x THW - RHO(TSW)

x CP(TSW) x TSW]

where: HWCAP = 750 gallons

HOT WATER LOAD (BTU)

HWL = HWSE + HWAT

HOT WATER ENERGY SAVINGS (BTU)

HWSVF = HWSE/FEFF

where FEFF = 0.60 (assumed boiler efficiency)

HOT WATER SOLAR FRACTION (%)

HWSFR = (HWSE/HWL) x 100 EXP

HOT WATER DEMAND SOLAR FRACTION (%)

HWDSFR = [HWSE/(HWSE + HWAT) x [1 - (EXP(-(HWAT + HWSE)/TANKV)] +

(HWDSFR_P/100) x (EXP(-(HWAT + HWSE)/TANKV)] x 100

NOTE: This equation proportions previously stored energy and auxiliary tank losses between solar and auxiliary energy.

HOT WATER SOLAR SAVINGS RATIO

HWSSR = HWSFR/100

SYSTEM PERFORMANCE FACTORS

SOLAR ENERGY FROM STORAGE (BTU)

CSEO = STEO

SOLAR ENERGY TO LOADS (BTU)

SEL = HWSE

COLLECTION SUBSYSTEM EFFICIENCY (%)

CSCEF = SEL/SEA x 100

SYSTEM LOAD (BTU)

SYSL = HWL

SYSTEM SOLAR FRACTION (%)

SFR = HWSFR

SYSTEM OPERATING ENERGY (BTU)

SYSOPE = CSOPE + HWOPE

AUXILIARY THERMAL ENERGY (BTU)

AXT = HWAT

AUXILIARY FOSSIL ENERGY (BTU)

AXF = HWAF

TOTAL ELECTRICAL SAVINGS (BTU)

TSVE = -CSOPE

TOTAL FOSSIL SAVINGS (BTU)

TSVF = HWSVF

TOTAL ENERGY CONSUMED (BTU)

TECSM = SYSOPE + SECA + AXF

SYSTEM SOLAR SAVINGS RATIO

SSSR = (SEL - CSOPE)/SYSL

APPENDIX C

CONVERSION FACTORS

APPENDIX C

CONVERSION FACTORS

Energy Conversion Factors

Fuel Type	Energy Content	Fuel Source Conversion Factor
Distillate fuel oil[1]	138,690 BTU/gallon	7.21×10^{-6} gallon/BTU
Residual fuel oil[2]	149,690 BTU/gallon	6.68×10^{-6} gallon/BTU
Kerosene	135,000 BTU/gallon	7.41×10^{-6} gallon/BTU
Propane	91,500 BTU/gallon	10.93×10^{-6} gallon/BTU
Natural gas	1,021 BTU/ cubic feet	979.4×10^{-6} cubic feet/ BTU
Electricity	3,413 BTU/ kilowatt-hour	292.8×10^{-6} kWh/BTU

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1 No. 1 and No. 2 heating oils, diesel fuel, No. 4 fuel oils

2 No. 5 and No. 6 fuel oils

APPENDIX D

SENSOR TECHNOLOGY

APPENDIX D

SENSOR TECHNOLOGY

TEMPERATURE SENSORS

Temperatures are measured by a Minco Products S43P platinum Resistance Temperature Detector (RTD). Because the resistance of platinum wire varies as a function of temperature, measurement of the resistance of a calibrated length of platinum wire can be used to accurately determine the temperature of the wire. This is the principle of the platinum RTD which utilizes a tiny coil of platinum wire encased in a copper-tipped probe to measure temperature.

Ambient temperature sensors are housed in a WeatherMeasure Radiation Shield in order to protect the probe from solar radiation. Care is taken to locate the sensor away from extraneous heat sources which could produce erroneous temperature readings. Temperature probes mounted in pipes are installed in stainless steel thermowells for physical protection of the sensor and to allow easy removal and replacement of the sensors. A thermally-conductive grease is used between the probe and the thermowell to assure faster temperature response.

All temperature sensors are individually calibrated at the factory. In addition, the bridge circuit is calibrated in the field using a five-point check.

Nominal Resistance @ 0°C:	100 ohms
No. of Leads:	3
Electrical Connection:	Wheatstone Bridge
Time Constant:	1.5 seconds max. in water at 3 fps
Self Heating:	27 mw/oF
Accuracy:	± 0.25°F
Accuracy in SFBP application	± 0.8°F

INSOLATION SENSORS

The Eppley Model PSP pyranometer is used for the measurement of insolation. The pyranometer consists of a circular multijunction thermopile of the plated, (copper-constantan) wirewound type which is temperature compensated to render the response essentially independent of ambient temperature. The receiver is coated with Parsons' black lacquer (non-wavelength-selective absorption). The instrument is supplied with a pair of precision-ground polished concentric hemispheres of Schott optical glass transparent to light between 285 and 2800 nm of wavelength. The instrument is provided with a dessicator which may be readily inspected.

Sensitivity:	9 $V/W/m^2$
Temperature Dependence:	± 1% over ambient temperature range -20°C to 40°C
Linearity:	0.5% from 0 to 2,800 W/M^2
Response Time:	1 second
Cosine Error:	± 1% 0-70° zenith angle ± 3% 70-80° zenith angle
Accuracy in SFBP application	± 2.5% of full scale

LIQUID FLOW SENSORS (NON-TOTALIZING)

The Ramapo Mark V strain gauge flow meters are used for the measurement of liquid flow. The flow meters sense the flow of the liquids by measuring the force exerted by the flow on a target suspended in the flow stream. This force is transmitted to a four active arm strain gauge bridge to provide a signal proportional to flow rate squared. The flow meters are available in a screwed end configuration, a flanged configuration, and a wafer configuration. Each flow meter is calibrated for the particular fluid being used in the application and flow calculations are corrected for change in fluid density due to temperature change (but not vicosity).

Materials:	Target - 17-PH stainless steel Body - Brass or stainless steel Seals - Buna-N
Fluid Temperature:	-40°F to 250°F
Calibration Accuracy:	± 1% (1/2" to 3-1/2" line size) ± 2% (4" and greater line size)
Repeatability and Hysteresis:	0.25% of reading
Accuracy in SFBP application	± 1.4% of full scale

LIQUID FLOW SENSORS (TOTALIZING)

Hersey Series 400 flow meters are used to measure totalized liquid flow. The meter is a nutating disk, positive displacement type meter. An R-15 register with an SPDT reed switch is used to provide an output to the data acquisition subsystem. The output of the reed switch is input to a Martin DR-1 Digital Ramp which counts the number of pulses and produces a zero to five volt analog signal corresponding to the pulse count.

Materials:	Meter body - bronze Measuring chamber - plastic
Accuracy:	± 1.5% of full scale
Accuracy in SFBP application	± 2% of full scale

FUEL OIL FLOW SENSOR

The Kent Mini-Major is used as a fuel oil flow meter. The meter utilizes an oscillating piston as a positive displacement element. The oscillating piston is connected to a pulser which sends pulses to the Site Data Acquisition Subsystem for totalization.

Operating Temperature:	100°C (max)
Flow Range:	0.6 to 48 gph
Accuracy:	± 1% of full scale
Accuracy in SFBP application	± 4% of full scale

FUEL GAS FLOW SENSOR

The American AC-175 gas meter is used for the measurement of totalized fuel gas flow. The drop in pressure between the inlet and outlet of the meter is responsible for the action of the meter. The principle of measurement is positive displacement. Four chambers in the meter fill and empty in sequence. The exact volume of compartments is known, so by counting the number of displacements, the volume is measured. Sliding control valves control the entrance and exit of the gas to the compartments. The meter is temperature compensated to reference all volumetric readings to 60°F.

Rated Capacity:	175 cubic ft/hr
Max Working Pressure:	5 psi
Accuracy in SFBP application	± 4% of full scale

ELECTRIC POWER SENSORS

Ohio Semitronics Series PC5 wattmeters are used as electric power sensors. They utilize Hall effect devices as multipliers taking the product of the instantaneous voltage and current readings to determine the electrical power. This technique automatically takes power factor into consideration and produces a true power reading.

Power Factor Range:	1 to 0 (lead or lag)
Response Time:	250 ms
Temperature Effect:	1% of reading
Accuracy:	± 0.5% of full scale
Accuracy in SFBP application	± 0.75% of full scale

ELAPSE TIMERS

The elapse timers used are Martin ET-1 0-30 minute Ramps which produce a zero to five volt analog output signal corresponding to the time that a switch is closed on the input side.

Range:	0 - 30 minutes
Accuracy in SFBP application	± 7 seconds

APPENDIX E

MONTHLY DATA

APPENDIX E

MONTHLY DATA

This appendix contains the monthly performance Tables for each month that the site was monitored. In April through July, the method of calculating the energy out of storage (STEO) was changed because of a need to account for the effect of DHW recirculattion on the solar energy used. For April through July the calculation of energy out of storage is a summation of solar energy used to meet the hot water demand and the solar energy used to makeup the losses in the hot water recirculation loop (See Equations in Appendix B - STEO.). This calculation of energy out of storage also affected the hot water load, hot water demand, storage losses and energy savings; these values are higher in the seasonal report tables in section V than is reported in the monthly report tables which follow.

MONTHLY REPORT: NOVEMBER 1984
SITE SUMMARY: TUCSON JOB CORPS - P-3077

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	74.990 MILLION BTU
	42176 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	17.432 MILLION BTU
	9804 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	53 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.15
ECSS OPERATING ENERGY	0.319 MILLION BTU
STORAGE EFFICIENCY	76.0 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	.49 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	1.711 MILLION BTU
TOTAL ENERGY CONSUMED	58.487 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	42.978	N.A.	N.A.	42.978 MILLION BTU
SOLAR FRACTION	37	N.A.	N.A.	37 PERCENT
SOLAR ENERGY USED	16.000	N.A.	N.A.	16.000 MILLION BTU
OPERATING ENERGY	1.388	N.A.	N.A.	1.711 MILLION BTU
AUX. THERMAL ENERGY	26.976	N.A.	N.A.	26.976 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	39.344	N.A.	N.A.	39.344 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.319 MILLION BTU
FOSSIL SAVINGS	26.667	N.A.	N.A.	26.667 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.77

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 68.58

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: NOVEMBER 1984
SITE SUMMARY: TUCSON JOB CORPS - P-3077

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	79.114 GIGA JOULES
	478955 KJ/SQ.M.
COLLECTED SOLAR ENERGY	18.391 GIGA JOULES
	111340 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	12 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.15
ECSS OPERATING ENERGY	0.336 GIGA JOULES
STORAGE EFFICIENCY	76.0 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.374 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	1.805 GIGA JOULES
TOTAL ENERGY CONSUMED	61.704 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	45.342	N.A.	N.A.	45.342 GIGA JOULES
SOLAR FRACTION	37	N.A.	N.A.	37 PERCENT
SOLAR ENERGY USED	16.880	N.A.	N.A.	16.880 GIGA JOULES
OPERATING ENERGY	1.464	N.A.	N.A.	1.805 GIGA JOULES
AUX. THERMAL ENG	28.460	N.A.	N.A.	28.460 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	41.508	N.A.	N.A.	41.508 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.336 GIGA JOULES
FOSSIL SAVINGS	28.134	N.A.	N.A.	28.134 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.77

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 68.58

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3067 NOVEMBER 1984

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	2.494#	53#	0.532#	N	0.011#	N	0.213#
2	2.494#	53#	0.532#	O	0.011#	O	0.213#
3	2.494#	53#	0.532#	T	0.011#	T	0.213#
4	2.494#	53#	0.532#		0.011#		0.213#
5	2.494#	53#	0.532#	A	0.011#	A	0.213#
6	2.494#	53#	0.532#	P	0.011#	P	0.213#
7	2.494#	53#	0.532#	P	0.011#	P	0.213#
8	2.494#	53#	0.532#	L	0.011#	L	0.213#
9	2.494#	53#	0.532#	I	0.011#	I	0.213#
10	2.494#	53#	0.532#	C	0.011#	C	0.213#
11	2.494#	53#	0.532#	A	0.011#	A	0.213#
12	2.273	60	0.667	B	0.014	B	0.294
13	3.661	58	1.104	L	0.020	L	0.302
14	3.978	60	0.598	E	0.022	E	0.150
15	2.494#	54#	0.336#		0.011#		0.135#
16	0.987	53	0.358#		0.003		0.363#
17	2.285	52	0.587		0.015		0.257
18	3.436	53	1.372		0.022		0.399
19	2.774	53	1.141		0.018		0.411
20	2.952	55	0.658		0.015		0.223
21	2.785	58	0.608		0.020		0.218
22	0.953	57	0.636		0.007		0.667
23	0.944	52	0.366		0.004		0.388
24	2.763	52	0.468		0.006		0.170
25	0.784	52	0.512		0.003		0.653
26	3.457	45	0.160		0.002		0.046
27	2.083	44	0.208		0.003		0.100
28	2.747	50	0.086		0.002		0.031
29	3.599	51	0.134		0.002		0.037
30	2.599	50	0.150		0.013		0.058
SUM	74.990	-	16.000	N.A.	0.319	N.A.	-
AVG	2.500	53	0.533	N.A.	0.011	N.A.	0.213
PFRV	0.3153	0.3153	0.3056	N.A.	0.3083	N.A.	0.3056

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3077 NOVEMBER 1984

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	2.494#	1.280#	0.566#	59#	0.227#	0.442#
2	2.494#	1.280#	0.566#	59#	0.227#	0.442#
3	2.494#	1.280#	0.566#	59#	0.227#	0.442#
4	2.494#	1.280#	0.566#	59#	0.227#	0.442#
5	2.494#	1.280#	0.566#	59#	0.227#	0.442#
6	2.494#	1.280#	0.566#	59#	0.227#	0.442#
7	2.494#	1.280#	0.566#	59#	0.227#	0.442#
8	2.494#	1.280#	0.566#	59#	0.227#	0.442#
9	2.494#	1.280#	0.566#	59#	0.227#	0.442#
10	2.494#	1.280#	0.566#	59#	0.227#	0.442#
11	2.494#	1.280#	0.566#	59#	0.227#	0.442#
12	2.273	1.730	0.779	72	0.343	0.450
13	3.661	2.777	1.496	69	0.409	0.539
14	3.978	3.556	1.799	58	0.452	0.506
15	2.494#	1.280#	0.502#	59#	0.201#	0.392#
16	0.987	0.344	0.161	61	0.163	0.467
17	2.285	1.714	0.735	61	0.322	0.429
18	3.436	3.158	1.516	65	0.441	0.480
19	2.774	2.209	1.001	53	0.361	0.453
20	2.952	2.131	1.005	60	0.340	0.471
21	2.785	2.404	1.102	52	0.396	0.458
22	0.953	0.400	0.101	56	0.106	0.252
23	0.944	0.322	0.154	51	0.163	0.476
24	2.763	0.555	0.280	53	0.101	0.505
25	0.784	0.282	0.121	59	0.155	0.430
26	3.457	0.339	0.173	48	0.050	0.509
27	2.083	0.253	0.071	35	0.034	0.282
28	2.747	0.334	0.163	59	0.059	0.490
29	3.599	0.216	0.085	60	0.024	0.391
30	2.599	0.626	-0.033	62	-0.013	-0.052
SUM	74.990	38.715	17.432	-	-	-
AVG	2.500	1.291	0.581	58	0.232	0.450
PFRV	0.3153	0.3153	0.3153	0.3153	0.3153	0.3153

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3067 NOVEMBER 1984

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	0.673#	0.532#	*	102#	*
2	0.673#	0.532#	*	102#	*
3	0.673#	0.532#	*	102#	*
4	0.673#	0.532#	*	102#	*
5	0.673#	0.532#	*	102#	*
6	0.673#	0.532#	*	102#	*
7	0.673#	0.532#	*	102#	*
8	0.673#	0.532#	*	102#	*
9	0.673#	0.532#	*	102#	*
10	0.673#	0.532#	*	102#	*
11	0.673#	0.532#	*	102#	*
12	0.808	0.667	-0.532	126	0.96
13	1.581	1.104	-0.255	111	1.30
14	1.909	0.598	0.295	125	1.45
15	0.641#	0.336#	-0.145	108#	0.78#
16	0.178	0.358#	-0.041	90	0.35
17	0.828	0.587	0.541	101	0.58
18	1.656	1.372	0.302	114	0.03
19	1.111	1.141	0.128	115	0.24
20	1.114	0.658	0.144	114	0.49
21	1.246	0.608	-0.192	107	1.58
22	0.171	0.636	0.169	109	1.14
23	0.185	0.366	-0.052	110	0.21
24	0.317	0.468	-0.088	108	0.11
25	0.137	0.512	-0.339	92	0.08
26	0.184	0.160	-0.020	80	0.12
27	0.124	0.208	0.070	83	0.37
28	0.176	0.086	0.077	80	0.04
29	0.107	0.134	-0.070	81	0.14
30	0.356	0.150	0.277	90	0.17
SUM	20.231	16.000	-.66	-	-
AVG	0.674	0.533	-.022	102	.49
PFRV	0.3153	0.3056	N.A.	0.3153	0.3153

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3067 NOVEMBER 1984

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
2	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
3	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
4	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
5	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
6	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
7	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
8	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
9	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
10	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
11	1.428#	37#	1.322#	53#	0.532#	0.046#	0.896#
12	1.276	52	1.276	73	0.667	0.045	0.609
13	1.67	66	1.481	81#	1.104	0.043	0.566
14	1.172	51	0.957	66#	0.598	0.044	0.574
15	0.991#	34#	0.882#	56#	0.336#	0.045#	0.655#
16	1.339#	27#	1.168#	55#	0.358#	0.047	0.981#
17	1.783	33	1.562	36	0.587	0.049	1.196
18	2.344	59	2.460	58	1.372	0.047	0.972
19	2.206	52	2.176	60#	1.141	0.048	1.065
20	1.014	65	0.860	73	0.658	0.045	0.356
21	1.199	51	1.064	83#	0.608	0.046	0.591
22	1.411	45	1.091	59	0.636	0.045	0.775
23	0.942	39	1.256	62	0.366	0.044	0.576
24	1.215	39	1.054	58#	0.468	0.043	0.747
25	1.38	37	1.197	49	0.512	0.045	0.868
26	0.743	22	0.513	48#	0.160	0.044	0.583
27	2.062	10	1.862	19#	0.208	0.048	1.854
28	1.570	5	1.506	8	0.086	0.050	1.483
29	1.428	9	1.341	11#	0.134	0.052	1.294
30	1.525	10	1.494	20#	0.150	0.049	1.376
SUM	42.978 E	-	39.747	-	16.000	1.388	26.976 E
AVG	1.433	37	1.325	51	0.533	0.046	0.899
PFRV	0.3056	0.3056	0.3056	0.2181	0.3056	0.3069	0.3056

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3067 NOVEMBER 1984

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	1.275#	N	0.886#	73#	130#	2869#	2869#	N
2	O	1.275#	O	0.886#	73#	130#	2869#	2869#	O
3	T	1.275#	T	0.886#	73#	130#	2869#	2869#	T
4		1.275#		0.886#	73#	130#	2869#	2869#	
5	A	1.275#	A	0.886#	73#	130#	2869#	2869#	A
6	P	1.275#	P	0.886#	73#	130#	2869#	2869#	P
7	P	1.275#	P	0.886#	73#	130#	2869#	2869#	P
8	L	1.275#	L	0.886#	73#	130#	2869#	2869#	L
9	I	1.275#	I	0.886#	73#	130#	2869#	2869#	I
10	C	1.275#	C	0.886#	73#	130#	2869#	2869#	C
11	A	1.275#	A	0.886#	73#	130#	2869#	2869#	A
12	B	0.967	B	1.112	74	133	2666	2656	B
13	L	0.635	L	1.840	75	139	2769	2769	L
14	E	0.641	E	0.997	74	133	1986	1986	E
15		1.040#		0.559#	73#	129#	1901#	1901#	
16		1.244		0.597#	73#	130#	2517#	2517#	
17		1.792		0.978	75	131	3334	3334	
18		1.622		2.287	74	132	5212	5212	
19		1.433		1.902	75	128	4914	4914	
20		0.681		1.096	74	132	1838	1838	
21		0.851		1.013	74	134	2150	2150	
22		2.679		1.060	73	131	2310	2310	
23		1.127		0.610	72	127	2727	2727	
24		0.600		0.781	73	132	2153	2153	
25		0.948		0.853	73	131	2523	2523	
26		1.278		0.267	73	129	1100	1100	
27		1.985		0.347	73	123	4488	4488	
28		2.529		0.144	73	125	3478	3478	
29		1.566		0.224	72	131	2801	2801	
30		1.692		0.249	73	120	3835	3835	
SUM	N.A.	39.344	N.A.	26.667	-	-	86259	86259	N.A.
AVG	N.A.	1.311	N.A.	0.889	73	129	2875	2875	N.A.
PFRV	N.A.	0.3153	N.A.	0.3056	0.3056	0.3056	0.3056	0.3056	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	1403#	N	53#	59#	N	N	N	*	*
2	1403#	O	53#	59#	O	O	O	*	*
3	1403#	T	53#	59#	T	T	T	*	*
4	1403#		53#	59#				*	*
5	1403#	A	53#	59#	A	A	A	*	*
6	1403#	P	53#	59#	P	P	P	*	*
7	1403#	P	53#	59#	P	P	P	*	*
8	1403#	L	53#	59#	L	L	L	*	*
9	1403#	I	53#	59#	I	I	I	*	*
10	1403#	C	53#	59#	C	C	C	*	*
11	1403#	A	53#	59#	A	A	A	*	*
12	1279	B	60	72	B	B	B	0	5
13	2059	L	58	69	L	L	L	1	0
14	2237	E	60	58	E	E	E	3	0
15	1403#		54#	59#				15	0
16	555		53	61				10	0
17	1285		52	61				13	0
18	1933		53	65				10	0
19	1560		53	53				10	0
20	1660		55	60				8	0
21	1566		58	52				4	0
22	536		57	56				6	0
23	531		52	51				12	0
24	1554		52	53				11	0
25	441		52	59				13	0
26	1944		45	48				23	0
27	1171		44	35				20	0
28	1545		50	59				17	0
29	2024		51	60				15	0
30	1462		50	62				16	0
SUM	42176	N.A.	-	-	-	-	-	328	8
AVG	1406	N.A.	53	58	N.A.	N.A.	N.A.	11	0
PFRV	0.3153	N.A.	0.3153	0.3153	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY PERFORMANCE TABLES

JANUARY 1985

MONTHLY REPORT: JANUARY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3092

GENERAL SITE DATA:	CONVENTIONAL UNITS
INCIDENT SOLAR ENERGY	83.473 MILLION BTU
	46948 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	15.415 MILLION BTU
	8670 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	50 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.08
ECSS OPERATING ENERGY	1.028 MILLION BTU
STORAGE EFFICIENCY	35.5 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.592 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.474 MILLION BTU
TOTAL ENERGY CONSUMED	67.422 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	44.460	N.A.	N.A.	44.460 MILLION BTU
SOLAR FRACTION	15	N.A.	N.A.	15 PERCENT
SOLAR ENERGY USED	6.58E	N.A.	N.A.	6.58E MILLION BTU
OPERATING ENERGY	1.446	N.A.	N.A.	2.474 MILLION BTU
AUX. THERMAL ENERGY	37.883	N.A.	N.A.	37.883 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	49.316	N.A.	N.A.	49.316 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.028 MILLION BTU
FOSSIL SAVINGS	9.82E	N.A.	N.A.	9.82E MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.75
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 13.39

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: JANUARY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3092

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	88.064 GIGA JOULES
	533137 KJ/SQ.M.
COLLECTED SOLAR ENERGY	16.263 GIGA JOULES
	98455 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	10 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.08
ECSS OPERATING ENERGY	1.084 GIGA JOULES
STORAGE EFFICIENCY	35.5 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.363 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.610 GIGA JOULES
TOTAL ENERGY CONSUMED	71.130 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	46.90	N.A.	N.A.	46.90 GIGA JOULES
SOLAR FRACTION	15	N.A.	N.A.	15 PERCENT
SOLAR ENERGY USED	6.94E	N.A.	N.A.	6.94EGIGA JOULES
OPERATING ENERGY	1.525	N.A.	N.A.	2.610 GIGA JOULES
AUX. THERMAL ENG	39.967	N.A.	N.A.	39.967 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	52.028	N.A.	N.A.	52.028 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.084 GIGA JOULES
FOSSIL SAVINGS	10.36	N.A.	N.A.	10.36 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.75

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 13.39

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	2.685	46	I	N	0.000	N	0.001
2	3.543	43		O	0.000	O	0.000
3	3.557	46		T	0.000	T	0.000
4	3.534	50			0.000		0.000
5	3.553	56		A	0.000	A	0.000
6	3.284	55		P	0.000	P	0.000
7	0.338	51		P	0.000	P	-0.002
8	0.701	51		L	0.000	L	0.000
9	3.284	47		I	0.027	I	0.000
10	3.402	48		C	0.069	C	0.000
11	3.118	49		A	0.065	A	0.127
12	2.977	49		B	0.067	B	0.156
13	2.860	44		L	0.067	L	0.172
14	2.692#	49#		E	0.042#	E	0.063#
15	2.692#	50#			0.033#		0.060#
16	3.509	47			0.060		0.128
17	3.483	47			0.067		0.154
18	3.533	49			0.066		0.137
19	3.576	51			0.067		0.151
20	3.474	52			0.067		0.238
21	3.399	55			0.067		0.153
22	0.968	55			0.067		0.268
23	0.361	50			0.066		-0.049
24	1.058	52			0.026		-0.137
25	1.465	55			0.000		-0.135
26	2.548#	53#			0.021#		0.071#
27	2.692#	50#			0.033#		0.060#
28	3.495	49			0.009		0.008
29	2.349	52			0.000		-0.043
30	2.105	48			0.000		-0.086
31	3.237	39	I		0.042		0.021
SUM	83.473	-	6.58	N.A.	1.028	N.A.	-
AVG	2.693	50	0.212	N.A.	0.033	N.A.	0.08
PFRV	0.8669	0.8669	0.8656	N.A.	0.8656	N.A.	0.8656

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	2.685	0.000	0.000	52	0.000	0.000
2	3.543	0.000	0.000	52	0.000	0.000
3	3.557	0.000	0.000	55	0.000	0.000
4	3.534	0.000	0.000	61	0.000	0.000
5	3.553	0.000	0.000	66	0.000	0.000
6	3.284	0.000	0.000	67	0.000	0.000
7	0.338	0.000	0.000	58	0.000	0.000
8	0.701	0.000	0.000	57	0.000	0.000
9	3.284	0.804	0.271	55	0.082	0.336
10	3.402	3.402	1.141	58	0.335	0.335
11	3.118	2.925	0.796	59	0.255	0.272
12	2.977	2.977	0.991	60	0.333	0.333
13	2.860	2.860	0.946	51	0.331	0.331
14	2.692#	1.409#	0.461#	58#	0.171#	0.327#
15	2.692#	1.409#	0.493#	58#	0.183#	0.350#
16	3.509	3.508	1.275	54	0.363	0.363
17	3.483	3.483	1.266	57	0.363	0.363
18	3.533	3.533	1.378	61	0.390	0.390
19	3.576	3.576	1.163	63	0.325	0.325
20	3.474	3.474	1.334	65	0.384	0.384
21	3.399	3.399	1.288	68	0.379	0.379
22	0.968	0.968	0.349	61	0.361	0.361
23	0.361	0.361	0.187	51	0.518	0.518
24	1.058	0.033	0.020	56	0.019	0.600
25	1.465	0.000	0.000	62	0.000	0.000
26	2.548#	1.336#	0.547#	58#	0.214#	0.409#
27	2.692#	1.409#	0.493#	58#	0.183#	0.350#
28	3.495	0.000	-0.070	56	-0.020	-0.020
29	2.349	0.000	0.000	59	0.000	0.000
30	2.105	0.000	0.000	51	0.000	0.000
31	3.237	3.018	1.086	44	0.335	0.360
SUM	83.473	43.885	15.415	-	-	-
AVG	2.693	1.416	0.497	58	0.185	0.351
PFRV	0.8669	0.8669	0.8669	0.8669	0.8669	0.8669

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <60% VALID DATA; PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	0.000	I	-0.010	70	I
2	0.000		0.005	70	
3	0.000		-0.003	70	
4	0.000		0.000	70	
5	0.000		-0.011	69	
6	0.000		0.000	69	
7	0.000		-0.008	68	
8	0.000		-0.008	68	
9	0.263		0.177	74	
10	1.110		0.637	101	
11	0.762		-0.192	108	
12	0.962		-0.079	99	
13	0.919		-0.056	90	
14	0.445		-0.136	83#	
15	0.480		*	83#	
16	1.247		0.335	98	
17	1.235		0.066	100	
18	1.347		0.143	103	
19	1.131		0.233	106	
20	1.302		-0.069	108	
21	1.258		0.066	106	
22	0.332		-0.353	84	
23	0.175		-0.168	71	
24	0.016		0.030	66	
25	0.000		0.033	68	
26	0.537		-0.005	81#	
27	0.480		*	83#	
28	-0.073		0.017	71	
29	0.000		-0.005	69	
30	0.000		-0.010	68	
31	1.063	I	0.253	90	I
SUM	14.987	6.58	0.222	-	-
AVG	0.483	0.212	0.007	83	0.97
PFRV	0.8656	0.8656	N.A.	0.8669	0.8669

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

HOT WATER SUBSYSTEM

DAY OF MONTH (NBS ID)	HOT WATER LOAD MILLION BTU (Q302)	SOLAR FR.OF LOAD PER. (N300)	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUP. WAT. TEMP DEG F (N305)	HOT WAT. TEMP DEG F (N307)	HOT WATER USED GAL (N308)
1	I	1	0.002	0.039	0.247	N	0.000	N	I	54	55	19
2	↓	0	0.000	0.039	0.246	O	0.000	O	↓	52	56	29
3		0	0.000	0.039	0.246	T	0.000	T		64	62	19
4		0	0.000	0.045	0.248		0.842			66	77	58
5		0	0.000	0.043	0.390	A	0.430	A		66	126	381
6		0	0.000	0.047	0.956	P	1.455	P		69	132	1534
7		0	0.000	0.050	1.068	P	1.738	P		70	123	2154
8		0	0.000	0.050	1.552	L	2.092	L		71	125	3264
9		0	0.000	0.050	1.420	I	1.968	I		71	124	3293
10		0	0.000	0.025	1.609	C	2.166	C		70	125	3205
11		26	0.395	0.022	1.101	A	1.476	A		71	123	3401
12		29	0.463	0.048	1.151	B	1.587	B		70	132	2668
13		25	0.490	0.051	1.486	L	2.149	L		71	135	3166
14		10#	0.170#	0.047#	1.135#	E	1.584#	E		68#	118#	2018#
15		9#	0.162#	0.046#	1.232#		1.590#			68#	118#	2432#
16		29	0.448	0.049	1.090		1.378			72	124	3006
17		28	0.537	0.048	1.388		1.582			71	125	3547
18		29	0.483	0.047	1.173		1.540			71	127	2795
19		33	0.540	0.047	1.081		1.417			70	131	2208
20		48	0.825	0.046	0.896		1.256			71	128	2565
21		30	0.519	0.047	1.218		1.418			71	125	2990
22		13	0.259	0.052	1.759		2.327			70	126	3518
23		-1	-0.017	0.052	1.873		2.404			71	124	3019
24		-7	-0.145	0.053	2.106		2.662			71	122	3391
25		-11	-0.198	0.052	1.948		2.274			71	122	3493
26		12#	0.182#	0.046#	0.931#		1.277#			68#	121#	1539#
27		9#	0.162#	0.046#	1.232#		1.590#			68#	118#	2432#
28		2	0.027	0.048	1.418		1.765			69	124	2391
29		-5	-0.100	0.053	2.025		2.509			70	125	3498
30	↓	-10	-0.180	0.053	2.022		2.732		↓	71	124	3450
31	I	4	0.066	0.050	1.622		2.094		I	70	125	3479
SUM	44.46	-	5.095	1.445	37.883	N.A.	49.315	N.A.	9.82E	-	-	74975
AVG	1.43	15	0.164	0.046	1.222	N.A.	1.590	N.A.	0.32	70	125	2418
PFRV	0.8656	0.866	0.8656	0.8656	0.8656	N.A.	0.8669	N.A.	0.8656	0.87	0.87	0.8656

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

HOT WATER SUBSYSTEM I

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER.	HOT WATER DEMAND MILLION BTU	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU
(NBS ID)		(N300)	(Q302)		(Q300)	(Q303)	(Q301)
1	I	1	0.000	I	0.002	0.039	0.247
2		0	0.001		0.000	0.039	0.246
3		0	0.000		0.000	0.040	0.246
4		0	0.005		0.000	0.045	0.248
5		0	0.192		0.000	0.043	0.390
6		0	0.799		0.000	0.047	0.957
7		0	0.944		-0.001	0.050	1.069
8		0	1.469		0.000	0.051	1.552
9		0	1.474		0.000	0.051	1.421
10		0	1.480		0.000	0.025	1.610
11		26	1.483		0.395	0.023	1.102
12		29	1.370		0.464	0.049	1.152
13		25	1.693		0.491	0.052	1.486
14		10#	0.944#		0.171#	0.047#	1.135#
15		9#	1.122#		0.163#	0.047#	1.232#
16		29	1.316		0.449	0.049	1.090
17		28	1.605		0.537	0.049	1.389
18		29	1.296		0.484	0.048	1.174
19		33	1.114		0.541	0.048	1.081
20		48	1.225		0.825	0.047	0.897
21		30	1.347		0.519	0.048	1.218
22		13	1.635		0.260	0.052	1.760
23		-1	1.351		-0.018	0.053	1.873
24		-7	1.440		-0.145	0.053	2.106
25		-11	1.467		-0.198	0.052	1.948
26		12#	0.780#		0.182#	0.046#	0.932#
27		9#	1.122#		0.163#	0.047#	1.232#
28		2	1.112		0.028	0.049	1.419
29		-5	1.581		-0.101	0.053	2.026
30		-10	1.528		-0.181	0.054	2.022
31	I	4	1.593	I	0.067	0.051	1.622
SUM	44.46	-	34.487	-	6.58	1.446	37.883
AVG	1.43	15	1.112	I	0.212	0.047	1.222
PFRV	0.8656	0.8656	0.8656	0.8656	0.8656	0.8656	0.8656

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.000	N	I	54	55	20	20	N
2	O	0.000	O		52	56	29	29	O
3	T	0.000	T		54	62	20	20	T
4		0.842			56	77	59	59	
5	A	0.430	A		56	126	381	381	A
6	P	1.456	P		69	132	1534	1534	P
7	P	1.738	P		70	123	2155	2155	P
8	L	2.092	L		71	125	3264	3264	L
9	I	1.969	I		71	124	3294	3294	I
10	C	2.166	C		70	125	3205	3205	C
11	A	1.477	A		71	123	3401	3401	A
12	B	1.588	B		70	132	2668	2668	B
13	L	2.149	L		71	135	3167	3167	L
14	E	1.585#	E		68#	118#	2019#	2019#	E
15		1.591#			68#	118#	2432#	2432#	
16		1.379			72	124	3007	3007	
17		1.582			71	125	3548	3548	
18		1.541			71	127	2795	2795	
19		1.417			70	131	2209	2209	
20		1.256			71	128	2565	2565	
21		1.419			71	125	2991	2991	
22		2.327			70	126	3518	3518	
23		2.405			71	124	3020	3020	
24		2.663			71	122	3392	3392	
25		2.274			71	122	3493	3493	
26		1.277#			68#	121#	1539#	1539#	
27		1.591#			68#	118#	2432#	2432#	
28		1.766			69	124	2391	2391	
29		2.510			70	125	3499	3499	
30		2.732			71	124	3450	3450	
31		2.094		I	70	125	3479	3479	
SUM	N.A.	49.316	N.A.	9.82	-	-	74976	74976	N.A.
AVG	N.A.	1.591	N.A.	0.32	70	125	2419	2419	N.A.
PFRV	N.A.	0.8669	N.A.	0.8656	0.8656	0.8656	0.8656	0.8656	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <60% VALID DATA; PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3092 JANUARY 1985

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	1510	N	46	52	N	N	N	19	0
2	1993	O	43	52	O	O	O	21	0
3	2000	T	46	55	T	T	T	18	0
4	1988		50	61				14	0
5	1998	A	56	66	A	A	A	6	0
6	1847	P	55	67	P	P	P	8	0
7	190	P	51	58	P	P	P	12	0
8	394	L	51	57	L	L	L	13	0
9	1847	I	47	55	I	I	I	17	0
10	1913	C	48	58	C	C	C	15	0
11	1754	A	49	59	A	A	A	14	0
12	1675	B	49	60	B	B	B	13	0
13	1609	L	44	51	L	L	L	18	0
14	1514#	E	49#	58#	E	E	E	24	0
15	1514#		50#	58#				*	*
16	1973		47	54				17	0
17	1959		47	57				16	0
18	1987		49	61				14	0
19	2011		51	63				13	0
20	1954		52	65				11	0
21	1912		55	68				7	0
22	545		55	61				9	0
23	203		50	51				15	0
24	595		52	56				10	0
25	824		55	62				9	0
26	1433#		53#	58#				11	0
27	1514#		50#	58#				*	*
28	1966		49	56				14	0
29	1321		52	59				13	0
30	1184		48	51				17	0
31	1821		39	44				25	0
SUM	46948	N.A.	-	-	-	-	-	445	0
AVG	1514	N.A.	50	58	N.A.	N.A.	N.A.	14	0
PFRV	0.8669	N.A.	0.8669	0.8669	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY PERFORMANCE TABLES

MARCH 1985

MONTHLY REPORT: MARCH 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3112

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	98.925 MILLION BTU
	59629 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	37.053 MILLION BTU
	22334 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	60 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.34
ECSS OPERATING ENERGY	0.922 MILLION BTU
STORAGE EFFICIENCY	91.88 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.323 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.088 MILLION BTU
TOTAL ENERGY CONSUMED	64.884 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	51.487	N.A.	N.A.	51.487 MILLION BTU
SOLAR FRACTION	62	N.A.	N.A.	62 PERCENT
SOLAR ENERGY USED	33.508	N.A.	N.A.	33.508 MILLION BTU
OPERATING ENERGY	1.074	N.A.	N.A.	2.088 MILLION BTU
AUX. THERMAL ENERGY	17.979	N.A.	N.A.	17.979 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	21.169	N.A.	N.A.	21.169 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.922 MILLION BTU
FOSSIL SAVINGS	50.011	N.A.	N.A.	50.011 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.83
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 20.98

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
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MONTHLY REPORT: MARCH 1985

SITE SUMMARY: TUCSON JOB CORPS - P-3112

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	104.366 GIGA JOULES
	677151 KJ/SQ.M.
COLLECTED SOLAR ENERGY	39.091 GIGA JOULES
	253630 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	16 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.34
ECSS OPERATING ENERGY	0.973 GIGA JOULES
STORAGE EFFICIENCY	91.88 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	1.837 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.203 GIGA JOULES
TOTAL ENERGY CONSUMED	68.452 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	54.318	N.A.	N.A.	54.318 GIGA JOULES
SOLAR FRACTION	62	N.A.	N.A.	62 PERCENT
SOLAR ENERGY USED	35.350	N.A.	N.A.	35.350 GIGA JOULES
OPERATING ENERGY	1.133	N.A.	N.A.	2.203 GIGA JOULES
AUX. THERMAL ENG	18.968	N.A.	N.A.	18.968 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	22.334	N.A.	N.A.	22.334 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.973 GIGA JOULES
FOSSIL SAVINGS	52.762	N.A.	N.A.	52.762 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.83

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 20.98

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	3.876	61	1.251	N	0.025	N	0.323
2	3.036	60	1.178	O	0.016	O	0.388
3	3.301	47	1.220	T	0.019	T	0.370
4	3.163	48	1.098		0.021		0.347
5	3.750	58	1.527	A	0.027	A	0.407
6	1.295	61	1.072	P	0.014	P	0.827
7	1.289	60	0.557	P	0.015	P	0.432
8	1.666	60	0.445	L	0.018	L	0.267
9	2.991	67	0.931	I	0.043	I	0.311
10	2.144	69	0.633	C	0.067	C	0.295
11	3.064#	63#	1.012#	A	0.047#	A	0.330#
12	3.181#	60#	1.079#	B	0.030#	B	0.339#
13	3.899	62	1.079#	L	0.026	L	0.277#
14	3.819	64	1.079#	E	0.022	E	0.283#
15	2.248	54	1.079#		0.015		0.480#
16	3.566	57	1.079#		0.022		0.303#
17	3.205	63	1.079#		0.019		0.337#
18	3.910	65	1.079#		0.019		0.276#
19	1.365	52	0.771		0.008		0.565
20	3.807	59	0.982		0.020		0.258
21	3.647	62	1.481		0.020		0.406
22	3.799	62	1.128		0.021		0.297
23	3.874	64	1.461		0.020		0.377
24	3.846	67	1.463		0.021		0.380
25	2.648	68	1.726		0.018		0.652
26	3.973	67	1.507		0.020		0.379
27	3.951	65	1.292		0.043		0.327
28	4.016	66	1.036		0.067		0.258
29	2.469	49	0.513		0.067		0.208
30	4.082	50	0.705		0.067		0.173
31	4.045	57	0.966		0.067		0.239
SUM	98.925	-	33.508	N.A.	0.922	N.A.	-
AVG	3.191	60	1.081	N.A.	0.030	N.A.	0.339
PFRV	0.9113	0.9113	0.7110	N.A.	0.9099	N.A.	0.7110

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	3.876	3.283	1.691	79	0.436	0.515
2	3.036	2.619	1.396	74	0.460	0.533
3	3.301	2.625	1.083	51	0.328	0.413
4	3.163	2.782	0.933	66	0.295	0.335
5	3.750	3.367	1.410	75	0.376	0.419
6	1.295	0.950	0.562	73	0.434	0.592
7	1.289	0.901	0.472	66	0.367	0.524
8	1.666	1.285	0.710	70	0.427	0.553
9	2.991	2.871	1.207	77	0.404	0.420
10	2.144	2.144	0.465	79	0.217	0.217
11	3.064#	2.671#	1.049#	71#	0.342#	0.393#
12	3.181#	2.734#	1.190#	71#	0.374#	0.435#
13	3.899	3.478	1.819	77	0.467	0.523
14	3.819	3.321	1.752	74	0.459	0.527
15	2.248	1.497	0.783	58	0.348	0.523
16	3.566	3.046	1.403	67	0.394	0.461
17	3.205	2.649	1.337	75	0.417	0.505
18	3.910	3.156	1.602	78	0.410	0.508
19	1.365	0.557	0.324	53	0.237	0.581
20	3.807	3.160	1.697	67	0.446	0.537
21	3.647	2.923	1.427	75	0.391	0.488
22	3.799	3.144	1.655	73	0.436	0.526
23	3.874	3.203	1.710	79	0.441	0.534
24	3.846	3.199	1.495	85	0.389	0.467
25	2.648	2.047	1.120	81	0.423	0.547
26	3.973	3.232	1.698	78	0.427	0.525
27	3.951	3.623	1.315	75	0.333	0.363
28	4.016	4.016	1.052	74	0.262	0.262
29	2.469	2.469	0.311	55	0.126	0.126
30	4.082	4.082	1.153	58	0.282	0.282
31	4.045	4.045	1.231	68	0.304	0.304
SUM	98.925	85.078	37.053	-	-	-
AVG	3.191	2.744	1.195	71	0.375	0.436
PFRV	0.9113	0.9113	0.9113	0.9113	0.9113	0.9113

* UNAVAILABLE: N.A. NOT APPLICABLE: I INVALID: E ESTIMATED: # <60% VALID DATA: PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.680	1.251	0.538	125	0.16
2	1.390	1.178	-0.134	130	0.46
3	1.071	1.220	-0.201	124	0.06
4	0.921	1.098	0.010	124	0.23
5	1.397	1.527	0.547	119	1.02
6	0.560	1.072	-0.726	101	0.51
7	0.469	0.557	-0.075	88	0.04
8	0.706	0.445	0.139	91	0.37
9	1.191	0.931	0.197	109	0.14
10	0.443	0.633	-0.095	106	0.24
11	1.031#	1.012#	-0.271	113#	0.55#
12	1.177#	1.079#	*	119#	*
13	1.806	1.079#	0.598	126	0.19
14	1.742	1.079#	-0.043	125	1.08
15	0.776	1.079#	-0.368	110	0.11
16	1.393	1.079#	0.739	120	0.63
17	1.327	1.079#	-0.274	135	0.68
18	1.592	1.079#	0.123	133	0.54
19	0.321	0.771	-0.757	103	0.57
20	1.686	0.982	0.701	115	0.00
21	1.417	1.481	-0.053	125	0.01
22	1.644	1.128	0.162	129	0.50
23	1.698	1.461	0.039	140	0.24
24	1.484	1.463	0.042	146	0.03
25	1.113	1.726	-0.427	125	0.30
26	1.689	1.507	0.280	124	0.16
27	1.292	1.292	-0.338	127	0.51
28	1.021	1.036	-0.064	119	0.09
29	0.282	0.513	-0.237	100	0.01
30	1.120	0.705	0.400	106	0.02
31	1.196	0.966	0.077	117	0.24
SUM	36.636	33.508	0.153	-	-
AVG	1.182	1.081	0.005	118	0.32
PFRV	0.9113	0.7110	N.A.	0.9113	0.9113

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	1.615	72	1.334	83	1.251	0.040	0.363
2	1.446	81	1.337	86	1.178	0.043	0.269
3	1.579	77	1.368	77	1.220	0.044	0.358
4	1.326	80	1.115	82	1.098	0.042	0.228
5	2.818	52	2.017	64	1.527	0.032	1.291
6	1.582	68	1.678	78	1.072	0.003	0.511
7	1.645	34	1.527	34	0.557	0.007	1.088
8	1.227	36	0.918	37	0.445	0.005	0.782
9	1.421	66	1.386	57	0.931	0.003	0.490
10	1.267	50	1.103	56	0.633	0.004	0.634
11	2.137#	44#	1.873#	46#	1.012#	0.027#	1.125#
12	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
13	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
14	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
15	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
16	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
17	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
18	1.644#	57#	1.292#	65#	1.079#	0.035#	0.565#
19	1.737	37	0.739	61	0.771	0.042	0.966
20	1.662	59	0.204	89	0.982	0.047	0.680
21	1.936	76	1.556	77	1.481	0.044	0.455
22	1.459	77	1.106	79	1.128	0.044	0.331
23	1.746	84	1.299	85	1.461	0.043	0.284
24	1.630	90	1.189	91	1.463	0.042	0.166
25	1.859	93	1.578	95	1.726	0.042	0.133
26	1.925	78	1.466	83	1.507	0.044	0.417
27	1.493	87	1.170	84	1.292	0.043	0.201
28	1.784	58	1.502	60	1.036	0.046	0.748
29	1.450	35	1.162	42	0.513	0.049	0.937
30	1.740	41	1.410	34	0.705	0.049	1.035
31	1.497	65	1.114	63	0.966	0.045	0.532
SUM	51.487	-	40.197	-	33.508	1.074	17.979
AVG	1.661	62	1.297	67	1.081	0.035	0.580
PFRV	0.7110	0.7110	0.7110	0.5551	0.7110	0.7110	0.7110

* UNAVAILABLE: N.A. NOT APPLICABLE: I INVALID: E ESTIMATED: # <60% VALID DATA: PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.434	N	1.867	72	138	2197	2197	N
2	O	0.401	O	1.758	72	142	2296	2296	O
3	T	0.535	T	1.821	72	136	2561	2561	T
4		0.340		1.639	71	139	1979	1979	
5	A	1.899	A	2.279	72	135	3758	3758	A
6	P	0.762	P	1.600	72	143	2844	2844	P
7	P	1.625	P	0.831	73	128	3343	3343	P
8	L	1.166	L	0.665	72	124	2131	2131	L
9	I	0.731	I	1.390	73	128	3020	3020	I
10	C	0.947	C	0.944	74	128	2443	2443	C
11	A	1.596#	A	1.510#	73#	126#	3880#	3880#	A
12	B	0.657#	B	1.610#	72#	131#	2041#	2041#	B
13	L	0.804#	L	1.610#	71#	131#	2582#	2582#	L
14	E	0.804#	E	1.610#	73#	132#	2582#	2582#	E
15		0.804#		1.610#	73#	132#	2582#	2582#	
16		0.804#		1.610#	73#	132#	2582#	2582#	
17		0.804#		1.610#	73#	132#	2582#	2582#	
18		0.804#		1.610#	73#	132#	2582#	2582#	
19		0.804#		1.151	73	127	2582#	2582#	
20		1.015		1.466	74	140	2582#	2582#	
21		0.680		2.210	74	134	3089	3089	
22		0.494		1.684	74	131	2306	2306	
23		0.424		2.181	74	133	2609	2609	
24		0.248		2.184	74	134	2375	2375	
25		0.199		2.576	74	140	2881	2881	
26		0.623		2.250	74	133	3010	3010	
27		0.300		1.928	74	135	2306	2306	
28		1.117		1.547	75	129	3352	3352	
29		1.399		0.765	75	126	2723	2723	
30		1.545		1.052	74	129	3088	3088	
31		0.793		1.441	75	129	2483	2483	
SUM	N.A.	25.615	N.A.	50.011	-	-	83371	83371	N.A.
AVG	N.A.	0.826	N.A.	1.613	73	132	2689	2689	N.A.
PFRV	N.A.	0.7110	N.A.	0.7110	0.7110	0.7110	0.7110	0.7110	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3112 MARCH 1985

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	2336	N	61	79	N	N	N	0	1
2	1830	O	60	74	O	O	O	1	0
3	1990	T	47	51	T	T	T	16	0
4	1907		48	66				16	0
5	2260	A	58	75	A	A	A	7	0
6	781	P	61	73	P	P	P	1	0
7	777	P	60	66	P	P	P	4	0
8	1004	L	60	70	L	L	L	4	0
9	1803	I	67	77	I	I	I	0	3
10	1292	C	69	79	C	C	C	0	5
11	1847#	A	63#	71#	A	A	A	6	0
12	1917#	B	60#	71#	B	B	B	*	*
13	2350	L	62	77	L	L	L	0	5
14	2302	E	64	74	E	E	E	0	1
15	1355		54	58				10	0
16	2149		57	67				7	0
17	1932		63	75				0	0
18	2357		65	78				0	1
19	823		52	53				11	0
20	2295		59	67				5	0
21	2198		62	75				3	0
22	2290		62	73				4	0
23	2335		64	79				0	0
24	2318		67	85				0	5
25	1596		68	81				0	3
26	2395		67	78				0	3
27	2382		65	75				1	0
28	2421		66	74				0	2
29	1488		49	55				16	0
30	2460		50	58				16	0
31	2439		57	68				9	0
SUM	59629	N.A.	-	-	-	-	-	141	28
AVG	1924	N.A.	60	71	N.A.	N.A.	N.A.	5	1
PFRV	0.9113	N.A.	0.9113	0.9113	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY PERFORMANCE TABLES

APRIL 1985

MONTHLY REPORT: APRIL 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3122

GENERAL SITE DATA:	CONVENTIONAL UNITS
INCIDENT SOLAR ENERGY	106.040 MILLION BTU
	63918 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	47.252 MILLION BTU
	28482 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	72 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.31
ECSS OPERATING ENERGY	0.587 MILLION BTU
STORAGE EFFICIENCY	71.50 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.694 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.051 MILLION BTU
TOTAL ENERGY CONSUMED	56.820 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	38.137@	N.A.	N.A.	38.137@MILLION BTU
SOLAR FRACTION	87	N.A.	N.A.	87 PERCENT
SOLAR ENERGY USED	33.113@	N.A.	N.A.	33.113@MILLION BTU
OPERATING ENERGY	1.464	N.A.	N.A.	2.051 MILLION BTU
AUX. THERMAL ENERGY	5.024	N.A.	N.A.	5.024 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	7.346	N.A.	N.A.	7.346 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.587 MILLION BTU
FOSSIL SAVINGS	49.422	N.A.	N.A.	49.422 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 2.69
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 7.16

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED. @ = SEE APRIL REPORT.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
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MONTHLY REPORT: APRIL 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3122

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	111.873 GIGA JOULES
	725858 KJ/SQ.M.
COLLECTED SOLAR ENERGY	49.851 GIGA JOULES
	323443 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	22 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.31
ECSS OPERATING ENERGY	0.619 GIGA JOULES
STORAGE EFFICIENCY	71.50 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.942 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.164 GIGA JOULES
TOTAL ENERGY CONSUMED	59.945 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	40.234 @	N.A.	N.A.	40.234@GIGA JOULES
SOLAR FRACTION	87	N.A.	N.A.	87 PERCENT
SOLAR ENERGY USED	34.934 @	N.A.	N.A.	34.934@GIGA JOULES
OPERATING ENERGY	1.545	N.A.	N.A.	2.164 GIGA JOULES
AUX. THERMAL ENG	5.300	N.A.	N.A.	5.300 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	7.750	N.A.	N.A.	7.750 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.619 GIGA JOULES
FOSSIL SAVINGS	52.141	N.A.	N.A.	52.141 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 2.69
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 7.16

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED. @ = SEE APRIL REPORT.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	4.057	66	0.577	N	0.045	N	0.142
2	4.045	75	1.730	O	0.023	O	0.428
3	3.510#	71#	1.476#	T	0.019#	T	0.421#
4	3.533#	72#	1.106#		0.019#		0.313#
5	4.002	72	0.824	A	0.021	A	0.206
6	3.928	71	0.655	P	0.019	P	0.167
7	3.914	75	0.837	P	0.020	P	0.214
8	3.766	79	1.312	L	0.020	L	0.349
9	3.839	78	1.418	I	0.020	I	0.369
10	3.639	77	1.310	C	0.019	C	0.360
11	3.780	77	1.379	A	0.021	A	0.365
12	3.849	76	1.253	B	0.022	B	0.326
13	3.918	77	0.820	L	0.021	L	0.209
14	3.923	79	1.015	E	0.021	E	0.259
15	3.793	79	1.213		0.020		0.320
16	2.785	79	1.484		0.016		0.533
17	3.893	78	1.098		0.022		0.282
18	3.434	68	1.448		0.018		0.422
19	4.001	67	1.090		0.021		0.273
20	4.022	70	0.636		0.019		0.158
21	0.898	64	0.998		0.003		1.111
22	3.691	65	0.705		0.020		0.191
23	3.927	71	1.345		0.021		0.342
24	3.926	76	1.442		0.022		0.367
25	3.879	74	1.468		0.021		0.378
26	3.175	61	1.261		0.014		0.397
27	0.828	54	0.733		0.001		0.886
28	2.346	58	0.335		0.015		0.143
29	3.919	66	0.782		0.021		0.199
30	3.822	77	1.364		0.022		0.357
SUM	106.040	-	33.113@	N.A.	0.587	N.A.	-
AVG	3.535	72	1.104	N.A.	0.020	N.A.	0.312
PFRV	0.9319	0.9319	0.9292	N.A.	0.9292	N.A.	0.9292

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

@ SEE APRIL REPORT

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	4.057	3.671	1.542	81	0.380	0.420
2	4.045	3.555	1.939	90	0.479	0.545
3	3.510#	2.900#	1.594#	83#	0.454#	0.550#
4	3.533#	2.901#	1.575#	83#	0.446#	0.543#
5	4.002	3.319	1.793	82	0.448	0.540
6	3.928	3.195	1.721	84	0.438	0.539
7	3.914	3.212	1.677	90	0.429	0.522
8	3.766	3.219	1.617	93	0.429	0.502
9	3.839	3.218	1.749	88	0.456	0.543
10	3.639	2.856	1.669	89	0.459	0.584
11	3.780	3.242	1.794	90	0.475	0.553
12	3.849	3.296	1.934	91	0.502	0.587
13	3.918	3.387	1.911	93	0.488	0.564
14	3.923	3.287	1.842	94	0.469	0.560
15	3.793	3.168	1.740	92	0.459	0.549
16	2.785	2.068	1.403	93	0.504	0.679
17	3.893	3.331	1.764	91	0.453	0.530
18	3.434	2.837	1.448	72	0.422	0.510
19	4.001	3.327	1.740	78	0.435	0.523
20	4.022	3.178	1.580	84	0.393	0.497
21	0.898	0.153	0.048	69	0.054	0.316
22	3.691	3.055	1.662	73	0.450	0.544
23	3.927	3.279	1.704	84	0.434	0.520
24	3.926	3.301	1.914	90	0.488	0.580
25	3.879	3.280	1.736	84	0.448	0.529
26	3.175	2.431	1.302	65	0.410	0.535
27	0.828	0.059	0.031	58	0.038	0.534
28	2.346	1.714	1.045	61	0.445	0.610
29	3.919	3.271	1.833	76	0.468	0.560
30	3.822	3.313	1.945	91	0.509	0.587
SUM	106.040	87.022	47.252	-	-	-
AVG	3.535	2.901	1.575	83	0.446	0.543
PFRV	0.9319	0.9319	0.9319	0.9319	0.9319	0.9319

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.522	0.577	0.583	127	0.55
2	1.929	1.730	0.063	140	0.20
3	1.585#	1.476#	-0.222	133#	0.50#
4	1.565#	1.106#	*	131#	*
5	1.782	0.824	0.257	134	1.05
6	1.709	0.655	0.281	146	0.97
7	1.664	0.837	0.085	156	0.86
8	1.606	1.312	-0.284	147	0.80
9	1.739	1.418	-0.020	135	0.56
10	1.660	1.310	-0.118	132	0.81
11	1.785	1.379	0.085	130	0.57
12	1.925	1.253	0.068	131	1.04
13	1.902	0.820	0.138	136	1.50
14	1.832	1.015	0.013	142	1.18
15	1.730	1.213	0.070	139	0.70
16	1.397	1.484	-0.346	129	0.48
17	1.755	1.098	0.306	129	0.64
18	1.438	1.448	-0.300	129	0.44
19	1.730	1.090	0.277	128	0.56
20	1.570	0.636	0.143	139	1.08
21	0.048	0.998	-0.816	118	0.23
22	1.652	0.705	0.558	117	0.70
23	1.694	1.345	0.033	132	0.49
24	1.904	1.442	-0.028	134	0.79
25	1.726	1.468	-0.040	133	0.47
26	1.294	1.261	-0.162	123	0.29
27	0.031	0.733	-0.635	99	0.14
28	1.039	0.335	0.451	98	0.59
29	1.822	0.782	0.385	124	1.05
30	1.935	1.364	0.001	135	0.92
SUM	46.971	33.113@	0.470	-	-
AVG	1.566	1.104	0.016	131	0.69@
PFRV	0.9319	0.9292	N.A.	0.9319	0.9319

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@ SEE APRIL REPORT.

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985

HOT WATER SUBSYSTEM

DAY OF MONTH (NBS ID)	HOT WATER LOAD MILLION BTU (Q302)	SOLAR FR.OF LOAD PER. (N300)	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUP. WAT. TEMP DEG F (N305)	HOT WAT. TEMP DEG F (N307)	HOT WATER USED GAL (N308)
1	1.260	46	0.576	0.046	0.683	N	0.867	N	0.860	75	132	2097
2	1.860	93	1.729	0.041	0.130	O	0.194	O	2.581	76	145	2521
3	1.650#	89#	1.476#	0.046#	0.174#	T	0.259#	T	2.203#	76#	139#	3048#
4	1.270#	86#	1.105#	0.048#	0.164#		0.246#		1.650#	77#	137#	2446#
5	0.993	83	0.823	0.051	0.169	A	0.252	A	1.229	76	132	2684
6	0.655	100	0.655	0.041	0.000	P	0.000	P	0.978	75	138	1163
7	0.836	100	0.836	0.041	0.000	P	0.000	P	1.249	76	150	1192
8	1.312	100	1.312	0.048	0.000	L	0.000	L	1.958	77	153	2052
9	1.470	96	1.418	0.044	0.052	I	0.077	I	2.116	77	142	2589
10	1.374	95	1.310	0.043	0.064	C	0.096	C	1.955	77	140	2721
11	1.507	91	1.378	0.050	0.129	A	0.192	A	2.057	77	134	2912
12	1.360	92	1.252	0.044	0.107	B	0.160	B	1.869	77	136	2823
13	0.819	100	0.819	0.047	0.000	L	0.000	L	1.223	77	130	2736
14	1.014	100	1.014	0.041	0.000	E	0.000	E	1.514	78	141	2414
15	1.212	100	1.212	0.041	0.000		0.000		1.810	78	142	2022
16	1.509	98	1.484	0.041	0.025		0.037		2.215	78	137	2785
17	1.276	86	1.098	0.055	0.178		0.266		1.639	78	126	2546
18	1.474	98	1.447	0.045	0.026		0.038		2.161	78	142	2775
19	1.344	81	1.090	0.056	0.254		0.379		1.627	78	129	2619
20	0.635	100	0.635	0.049	0.000		0.000		0.948	77	132	1896
21	1.281	78	0.997	0.051	0.284		0.424		1.488	78	131	2355
22	1.103	64	0.704	0.053	0.398		0.594		1.051	77	131	2165
23	1.407	96	1.344	0.048	0.062		0.093		2.007	77	135	2795
24	1.468	98	1.442	0.041	0.026		0.038		2.152	78	144	2279
25	1.543	95	1.467	0.043	0.075		0.112		2.190	78	140	2570
26	1.354	93	1.260	0.046	0.094		0.140		1.881	78	132	2639
27	1.461	50	0.733	0.079	0.728		1.086		1.094	77	125	2931
28	1.118	30	0.335	0.073	0.782		1.168		0.500	77	123	2531
29	1.168	67	0.781	0.052	0.386		0.576		1.166	76	130	2448
30	1.389	98	1.363	0.041	0.025		0.037		2.035	77	140	2448
SUM	38.136@	-	33.113@	1.464	5.023	N.A.	7.345	N.A.	49.422	-	-	73214
AVG	1.271	87	1.103	0.048	0.167	N.A.	0.244	N.A.	1.647	77	136	2440
PFRV	0.9292	0.929	0.9292	0.9292	0.9292	N.A.	0.9319	N.A.	0.9292	0.93	0.93	0.9292

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.
@ SEE APRIL REPORT.

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985
HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	1.261	46	0.995	43	0.577	0.046	0.684
2	1.860	93	1.466	93	1.730	0.042	0.130
3	1.651#	89#	1.576#	88#	1.476#	0.047#	0.174#
4	1.270#	86#	1.185#	85#	1.106#	0.049#	0.165#
5	0.993	83	1.227	74	0.824	0.052	0.169
6	0.655	100	0.607	92	0.655	0.042	0.000
7	0.837	100	0.726	98	0.837	0.042	0.000
8	1.312	100	1.294	100	1.312	0.049	0.000
9	1.470	96	1.403	97	1.418	0.045	0.052
10	1.375	95	1.423	98	1.310	0.044	0.065
11	1.508	91	1.380	91	1.379	0.050	0.129
12	1.360	92	1.375	90	1.253	0.044	0.108
13	0.820	100	1.193	98	0.820	0.047	0.000
14	1.015	100	1.249	100	1.015	0.042	0.000
15	1.213	100	1.074	100	1.213	0.042	0.000
16	1.510	98	1.350	99	1.484	0.042	0.025
17	1.277	86	0.998	87	1.098	0.056	0.178
18	1.474	98	1.475	97	1.448	0.046	0.026
19	1.344	81	1.108	76	1.090	0.056	0.254
20	0.636	100	0.867	95	0.636	0.050	0.000
21	1.282	78	1.042	86	0.998	0.051	0.284
22	1.103	64	0.960	57	0.705	0.054	0.398
23	1.408	96	1.338	93	1.345	0.049	0.063
24	1.468	98	1.253	97	1.442	0.042	0.026
25	1.543	95	1.314	95	1.468	0.043	0.076
26	1.355	93	1.200	95	1.261	0.047	0.094
27	1.461	50	1.169	63	0.733	0.079	0.728
28	1.118	30	0.968	24	0.335	0.073	0.783
29	1.168	67	1.098	56	0.782	0.052	0.386
30	1.389	98	1.288	95	1.364	0.042	0.025
SUM	38.137@	-	35.602	-	33.113@	1.464	5.024
AVG	1.271	87	1.187	86	1.104	0.049	0.167
PFRV	0.9292	0.9292	0.9292	0.8569	0.9292	0.9292	0.9292

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.
@ SEE APRIL REPORT

MONTHLY REPORT: TUCSON JOB CORPS - P-3122 APRIL 1985

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.868	N	0.861	75	132	2098	2098	N
2	O	0.195	O	2.582	76	145	2522	2522	O
3	T	0.260#	T	2.203#	76#	139#	3049#	3049#	T
4		0.246#		1.650#	77#	137#	2447#	2447#	
5	A	0.253	A	1.230	76	132	2684	2684	A
6	P	0.000	P	0.978	75	138	1163	1163	P
7	P	0.000	P	1.249	76	150	1192	1192	P
8	L	0.000	L	1.959	77	153	2052	2052	L
9	I	0.078	I	2.117	77	142	2590	2590	I
10	C	0.097	C	1.955	77	140	2721	2721	C
11	A	0.193	A	2.057	77	134	2913	2913	A
12	B	0.161	B	1.870	77	136	2824	2824	B
13	L	0.000	L	1.224	77	130	2736	2736	L
14	E	0.000	E	1.515	78	141	2415	2415	E
15		0.000		1.810	78	142	2022	2022	
16		0.038		2.215	78	137	2785	2785	
17		0.266		1.639	78	126	2547	2547	
18		0.039		2.161	78	142	2776	2776	
19		0.379		1.628	78	129	2619	2619	
20		0.000		0.949	77	132	1896	1896	
21		0.424		1.489	78	131	2355	2355	
22		0.595		1.052	77	131	2166	2166	
23		0.094		2.007	77	135	2795	2795	
24		0.039		2.152	78	144	2279	2279	
25		0.113		2.191	78	140	2570	2570	
26		0.141		1.881	78	132	2639	2639	
27		1.087		1.095	77	125	2932	2932	
28		1.169		0.500	77	123	2531	2531	
29		0.577		1.167	76	130	2448	2448	
30		0.038		2.035	77	140	2448	2448	
SUM	N.A.	7.346	N.A.	49.422	-	-	73215	73215	N.A.
AVG	N.A.	0.245	N.A.	1.647	77	136	2440	2440	N.A.
PFRV	N.A.	0.9319	N.A.	0.9292	0.9292	0.9292	0.9292	0.9292	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3136 APRIL 1985

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	2445	N	66	81	N	N	N	0	2
2	2438	O	75	90	O	O	O	0	14
3	2116#	T	71#	83#	T	T	T	9	0
4	2129#		72#	83#				*	*
5	2412	A	72	82	A	A	A	0	7
6	2368	P	71	84	P	P	P	0	6
7	2359	P	75	90	P	P	P	0	12
8	2270	L	79	93	L	L	L	0	16
9	2314	I	78	88	I	I	I	0	16
10	2193	C	77	89	C	C	C	0	12
11	2279	A	77	90	A	A	A	0	14
12	2320	B	76	91	B	B	B	0	12
13	2362	L	77	93	L	L	L	0	12
14	2365	E	79	94	E	E	E	0	14
15	2286		79	92				0	14
16	1679		79	93				0	14
17	2346		78	91				0	12
18	2070		68	72				0	3
19	2412		67	78				0	5
20	2424		70	84				0	5
21	541		64	69				1	0
22	2225		65	73				0	0
23	2367		71	84				0	7
24	2366		76	90				0	10
25	2338		74	84				0	7
26	1914		61	65				5	0
27	499		54	58				10	0
28	1414		58	61				1	0
29	2362		66	76				0	3
30	2304		77	91				0	15
SUM	63918	N.A.	-	-	-	-	-	28	240
AVG	2131	N.A.	72	83	N.A.	N.A.	N.A.	1	8
PFRV	0.9319	N.A.	0.9319	0.9319	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY PERFORMANCE TABLES

MAY 1985

MONTHLY REPORT: MAY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3141

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	108.860 MILLION BTU
	65618 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	47.019 MILLION BTU
	28342 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	80 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.32
ECSS OPERATING ENERGY	0.608 MILLION BTU
STORAGE EFFICIENCY	73.68 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.681@BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.015 MILLION BTU
TOTAL ENERGY CONSUMED	52.690 MILLION BTU

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	36.812@	N.A.	N.A.	36.812@MILLION BTU
SOLAR FRACTION	94@	N.A.	N.A.	94@PERCENT
SOLAR ENERGY USED	34.388@	N.A.	N.A.	34.388@MILLION BTU
OPERATING ENERGY	1.407	N.A.	N.A.	2.015 MILLION BTU
AUX. THERMAL ENERGY	2.424	N.A.	N.A.	2.424 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	4.005	N.A.	N.A.	4.005 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.608 MILLION BTU
FOSSIL SAVINGS	51.326	N.A.	N.A.	51.326 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 3.44
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 24.35

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
READ THIS BEFORE TURNING PAGE.

@ SEE MAY REPORT.

MONTHLY REPORT: MAY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3141

GENERAL SITE DATA:	SI UNITS
INCIDENT SOLAR ENERGY	114.848 GIGA JOULES
	745159 KJ/SQ.M.
COLLECTED SOLAR ENERGY	49.605 GIGA JOULES
	321852 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	27 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.32
ECSS OPERATING ENERGY	0.641 GIGA JOULES
STORAGE EFFICIENCY	73.68 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.870 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.125 GIGA JOULES
TOTAL ENERGY CONSUMED	55.588 GIGA JOULES

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	38.837@	N.A.	N.A.	38.837@GIGA JOULES
SOLAR FRACTION	94@	N.A.	N.A.	94@PERCENT
SOLAR ENERGY USED	36.280@	N.A.	N.A.	36.280@GIGA JOULES
OPERATING ENERGY	1.484	N.A.	N.A.	2.125 GIGA JOULES
AUX. THERMAL ENG	2.557	N.A.	N.A.	2.557 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	4.225	N.A.	N.A.	4.225 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.641 GIGA JOULES
FOSSIL SAVINGS	54.149	N.A.	N.A.	54.149 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 3.44
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 24.35

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

@ SEE MAY REPORT.

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	3.686	81	1.105	N	0.022	N	0.300
2	3.760	83	1.428	O	0.023	O	0.380
3	3.609	85	1.136	T	0.022	T	0.315
4	3.845	80	1.124		0.021		0.292
5	3.561	78	1.144	A	0.020	A	0.321
6	3.473#	78#	1.632#	P	0.020#	P	0.470#
7	3.512#	80#	1.147#	P	0.020#	P	0.327#
8	3.817	83	0.896	L	0.021	L	0.235
9	2.650	82	1.251	I	0.015	I	0.472
10	3.883	74	1.159	C	0.020	C	0.298
11	3.935	70	1.212	A	0.020	A	0.308
12	3.908	71	1.451	B	0.020	B	0.371
13	3.927	71	1.282	L	0.020	L	0.326
14	3.971	77	1.512	E	0.022	E	0.381
15	3.405#	78#	0.760#		0.018#		0.223#
16	1.352	77	1.289		0.015		0.953
17	3.400	80	0.737		0.019		0.217
18	3.846	82	0.856		0.021		0.223
19	3.861	79	1.312		0.020		0.340
20	3.888	80	1.051		0.021		0.270
21	3.842	79	1.232		0.020		0.321
22	3.503	80	1.112		0.020		0.317
23	3.512#	80#	1.147#		0.020#		0.327#
24	3.601	85	0.846		0.020		0.235
25	3.764	86	0.807		0.020		0.214
26	3.865	85	0.893		0.019		0.231
27	3.512#	80#	1.147#		0.020#		0.327#
28	3.890	85	1.107		0.018		0.285
29	2.891	83	1.012		0.020		0.350
30	1.581	79	0.904		0.011		0.572
31	3.611	81	0.696		0.021		0.193
SUM	108.860	-	34.388@	N.A.	0.608	N.A.	-
AVG	3.512	80	1.109	N.A.	0.020	N.A.	0.316
PFRV	0.7634	0.7634	0.7527	N.A.	0.7527	N.A.	0.7527

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	3.686	3.266	1.646	96	0.447	0.504
2	3.760	3.404	1.786	94	0.475	0.525
3	3.609	3.041	1.632	96	0.452	0.537
4	3.845	3.123	1.646	92	0.428	0.527
5	3.561	2.813	1.394	89	0.392	0.496
6	3.473#	2.839#	1.526#	92#	0.439#	0.538#
7	3.512#	2.839#	1.526#	92#	0.435#	0.538#
8	3.817	3.238	2.000	97	0.524	0.618
9	2.650	1.950	1.136	96	0.429	0.582
10	3.883	3.068	1.660	77	0.428	0.541
11	3.935	3.214	1.831	80	0.465	0.570
12	3.908	3.169	1.652	82	0.423	0.522
13	3.927	3.056	1.701	80	0.433	0.556
14	3.971	3.348	1.790	91	0.451	0.535
15	3.405#	2.432#	1.334#	82#	0.392#	0.549#
16	1.352	0.944	0.525	87	0.389	0.557
17	3.400	2.845	1.592	89	0.468	0.560
18	3.846	3.145	1.717	97	0.446	0.546
19	3.861	3.090	1.590	91	0.412	0.515
20	3.888	3.180	1.729	92	0.445	0.544
21	3.842	3.138	1.567	90	0.408	0.499
22	3.503	2.732	1.427	89	0.407	0.522
23	3.512#	2.839#	1.526#	92#	0.435#	0.538#
24	3.601	2.941	1.660	104	0.461	0.565
25	3.764	3.062	1.646	102	0.437	0.537
26	3.865	2.984	1.474	99	0.381	0.494
27	3.512#	2.839#	1.526#	92#	0.435#	0.538#
28	3.890	2.828	1.519	101	0.390	0.537
29	2.891	2.266	1.196	92	0.414	0.528
30	1.581	0.920	0.524	87	0.331	0.569
31	3.611	2.964	1.540	92	0.426	0.519
SUM	108.860	87.514	47.019	-	-	-
AVG	3.512	2.823	1.517	91	0.432	0.537
PFRV	0.7634	0.7634	0.7634	0.7634	0.7634	0.7634

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.637	1.105	-0.070	135	1.05
2	1.776	1.428	0.031	136	0.56
3	1.623	1.136	0.068	138	0.74
4	1.637	1.124	0.144	143	0.55
5	1.384	1.144	-0.071	145	0.44
6	1.518#	1.632#	-0.101	139#	0.02#
7	1.518#	1.147#	*	136#	*
8	1.992	0.896	0.740	134	0.66
9	1.130	1.251	-0.286	131	0.32
10	1.650	1.159	0.253	129	0.40
11	1.820	1.212	0.078	139	0.73
12	1.641	1.451	-0.099	140	0.39
13	1.690	1.282	0.040	136	0.53
14	1.780	1.512	-0.023	137	0.45
15	1.326#	0.760#	-0.605	135#	1.93#
16	0.523	1.289	-0.133	112	1.69
17	1.586	0.737	0.521	114	0.91
18	1.709	0.856	0.465	133	0.70
19	1.580	1.312	-0.016	141	0.43
20	1.719	1.051	0.085	140	0.92
21	1.556	1.232	-0.009	141	0.51
22	1.419	1.112	-0.342	136	1.08
23	1.518#	1.147#	*	136#	*
24	1.652	0.846	0.330	138	0.84
25	1.636	0.807	0.238	149	0.88
26	1.464	0.893	0.251	153	0.44
27	1.518#	1.147#	*	136#	*
28	1.509	1.107	0.238	146	0.25
29	1.188	1.012	-0.163	136	0.60
30	0.521	0.904	-0.283	117	0.25
31	1.532	0.696	0.429	128	0.82
SUM	46.750	34.388@	0.057	-	-
AVG	1.508	1.109	0.002	136	0.68
PFRV	0.7634	0.7527	N.A.	0.7634	0.7634

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <[illegible]0% VALID DATA; PERV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

HOT WATER SUBSYSTEM

DAY OF MONTH (NBS ID)	HOT WATER LOAD MILLION BTU (Q302)	SOLAR FR.OF LOAD PER. (N300)	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUP. WAT. TEMP DEG F (N305)	HOT WAT. TEMP DEG F (N307)	HOT WATER USED GAL (N308)
1	1.132	98	1.105	0.042	0.026	N	0.039	N	1.649	78	151	1567
2	1.454	98	1.428	0.041	0.026	O	0.038	O	2.131	78	141	2355
3	1.160	98	1.135	0.041	0.024	T	0.035	T	1.695	78	143	1837
4	1.124	100	1.124	0.041	0.000		0.000		1.678	78	138	1925
5	1.144	100	1.144	0.041	0.000	A	0.000	A	1.707	79	146	1710
6	1.691#	97#	1.632#	0.043#	0.059#	P	0.088#	P	2.435#	78#	141#	2762#
7	1.215#	96#	1.147#	0.045#	0.067#	P	0.113#	P	1.712#	79#	140#	1972#
8	1.090	82	0.895	0.047	0.195	L	0.549	L	1.336	79	148	1242
9	1.274	98	1.251	0.041	0.022	I	0.033	I	1.867	79	139	2272
10	1.249	93	1.158	0.054	0.090	C	0.135	C	1.729	79	129	2384
11	1.211	100	1.211	0.046	0.000	A	0.000	A	1.808	78	134	2247
12	1.451	100	1.451	0.041	0.000	B	0.000	B	2.166	79	140	2482
13	1.308	98	1.282	0.041	0.026	L	0.039	L	1.913	79	141	2111
14	1.539	98	1.511	0.041	0.028	E	0.041	E	2.256	79	143	2472
15	0.836#	92#	0.760#	0.042#	0.076#		0.113#		1.134#	80#	147#	1062#
16	1.848	70	1.288	0.054	0.559		0.837		1.923	80	123	3722
17	1.030	72	0.737	0.056	0.293		0.513		1.100	80	141	1229
18	1.042	82	0.856	0.061	0.186		0.278		1.277	80	129	1705
19	1.313	100	1.312	0.041	0.001		0.001		1.958	80	142	2117
20	1.067	98	1.050	0.041	0.016		0.024		1.568	79	145	1549
21	1.237	100	1.232	0.041	0.005		0.007		1.838	79	146	1856
22	1.155	97	1.111	0.042	0.043		0.064		1.659	79	142	1811
23	1.215#	96#	1.147#	0.045#	0.067#		0.113#		1.712#	79#	140#	1972#
24	0.886	96	0.845	0.043	0.040		0.072		1.262	79	141	1351
25	0.806	100	0.806	0.041	0.000		0.000		1.203	80	140	1163
26	0.904	100	0.893	0.042	0.011		0.017		1.332	81	149	1189
27	1.215#	96#	1.147#	0.045#	0.067#		0.113#		1.712#	79#	140#	1972#
28	1.113	100	1.107	0.042	0.006		0.011		1.652	81	151	1496
29	1.012	100	1.012	0.046	0.000		0.000		1.510	81	142	1651
30	1.179	77	0.903	0.049	0.276		0.412		1.348	81	126	2159
31	0.899	77	0.696	0.050	0.203		0.303		1.039	81	132	1471
SUM	36.812@	-	34.388@	1.406	2.423	N.A.	4.004	N.A.	51.326	-	-	58830
AVG	1.187	94@	1.109	0.045	0.078	N.A.	0.129	N.A.	1.655	79	139	1897
PFRV	0.7527	0.753	0.7527	0.7527	0.7527	N.A.	0.7634	N.A.	0.7527	0.75	0.75	0.7527

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

@ SEE MAY REPORT.

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	1.132	98	0.946	97	1.105	0.042	0.027
2	1.454	98	1.270	98	1.428	0.042	0.026
3	1.160	98	0.989	98	1.136	0.042	0.024
4	1.124	100	0.955	99	1.124	0.042	0.000
5	1.144	100	0.951	100	1.144	0.042	0.000
6	1.691#	97#	1.447#	96#	1.632#	0.044#	0.059#
7	1.215#	96#	0.983#	93#	1.147#	0.045#	0.068#
8	1.091	82	0.704	85	0.896	0.048	0.195
9	1.274	98	1.135	97	1.251	0.042	0.023
10	1.250	93	0.986	93	1.159	0.055	0.091
11	1.212	100	1.035	98	1.212	0.047	0.000
12	1.451	100	1.254	100	1.451	0.042	0.000
13	1.309	98	1.086	98	1.282	0.042	0.027
14	1.540	98	1.340	98	1.512	0.042	0.028
15	0.837#	92#	0.591#	93#	0.760#	0.043#	0.076#
16	1.849	70	1.333	78	1.289	0.055	0.560
17	1.030	72	0.631	67	0.737	0.057	0.293
18	1.043	82	0.705	75	0.856	0.062	0.187
19	1.314	100	1.085	98	1.312	0.042	0.001
20	1.067	98	0.853	99	1.051	0.042	0.017
21	1.237	100	1.061	99	1.232	0.042	0.005
22	1.155	97	0.936	96	1.112	0.042	0.043
23	1.215#	96#	0.983#	93#	1.147#	0.045#	0.068#
24	0.886	96	0.669	95	0.846	0.044	0.040
25	0.807	100	0.583	99	0.807	0.042	0.000
26	0.905	100	0.685	99	0.893	0.042	0.012
27	1.215#	96#	0.983#	93#	1.147#	0.045#	0.068#
28	1.114	100	0.930	99	1.107	0.043	0.007
29	1.012	100	0.828	100	1.012	0.047	0.000
30	1.180	77	0.803	89	0.904	0.050	0.276
31	0.899	77	0.622	70	0.696	0.050	0.203
SUM	36.812@	-	29.360	-	34.388@	1.407	2.424
AVG	1.187	94@	0.947	94	1.109	0.045	0.078
PERV	0.7527	0.7527	0.7527	0.7527	0.7527	0.7527	0.7527

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PERV RELIABILITY VALUE

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.040	N	1.650	78	151	1567	1567	N
2	O	0.039	O	2.132	78	141	2355	2355	O
3	T	0.036	T	1.695	78	143	1837	1837	T
4		0.000		1.678	78	138	1925	1925	
5	A	0.000	A	1.708	79	146	1710	1710	A
6	P	0.088#	P	2.436#	78#	141#	2762#	2762#	P
7	P	0.114#	P	1.712#	79#	140#	1973#	1973#	P
8	L	0.550	L	1.337	79	148	1243	1243	L
9	I	0.034	I	1.868	79	139	2273	2273	I
10	C	0.136	C	1.729	79	129	2385	2385	C
11	A	0.000	A	1.808	78	134	2248	2248	A
12	B	0.000	B	2.166	79	140	2482	2482	B
13	L	0.040	L	1.914	79	141	2112	2112	L
14	E	0.042	E	2.256	79	143	2473	2473	E
15		0.114#		1.135#	80#	147#	1062#	1062#	
16		0.837		1.924	80	123	3723	3723	
17		0.514		1.101	80	141	1229	1229	
18		0.278		1.278	80	129	1705	1705	
19		0.002		1.959	80	142	2118	2118	
20		0.025		1.568	79	145	1549	1549	
21		0.008		1.839	79	146	1857	1857	
22		0.065		1.659	79	142	1812	1812	
23		0.114#		1.712#	79#	140#	1973#	1973#	
24		0.072		1.263	79	141	1351	1351	
25		0.000		1.204	80	140	1163	1163	
26		0.017		1.333	81	149	1190	1190	
27		0.114#		1.712#	79#	140#	1973#	1973#	
28		0.011		1.652	81	151	1497	1497	
29		0.000		1.511	81	142	1652	1652	
30		0.412		1.349	81	126	2160	2160	
31		0.303		1.039	81	132	1472	1472	
SUM	N.A.	4.005	N.A.	51.326	-	-	58831	58831	N.A.
AVG	N.A.	0.129	N.A.	1.656	79	139	1898	1898	N.A.
PFRV	N.A.	0.7634	N.A.	0.7527	0.7527	0.7527	0.7527	0.7527	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3141 MAY 1985

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	2222	N	81	96	N	N	N	0	18
2	2266	O	83	94	O	O	O	0	20
3	2175	T	85	96	T	T	T	0	21
4	2317		80	92				0	14
5	2146	A	78	89	A	A	A	0	14
6	2093#	P	78#	92#	P	P	P	4	0
7	2117#	P	80#	92#	P	P	P	*	*
8	2301	L	83	97	L	L	L	0	21
9	1597	I	82	96	I	I	I	0	19
10	2340	C	74	77	C	C	C	0	8
11	2372	A	70	80	A	A	A	0	6
12	2356	B	71	82	B	B	B	0	4
13	2367	L	71	80	L	L	L	0	5
14	2393	E	77	91	E	E	E	0	14
15	2052#		78#	82#				0	8
16	815		77	87				0	16
17	2050		80	89				0	14
18	2318		82	97				0	15
19	2327		79	91				0	12
20	2344		80	92				0	15
21	2316		79	90				0	13
22	2111		80	89				0	11
23	2117#		80#	92#				*	*
24	2171		85	104				0	27
25	2269		86	102				0	20
26	2330		85	99				0	18
27	2117#		80#	92#				*	*
28	2345		85	101				0	20
29	1743		83	92				0	16
30	953		79	87				0	16
31	2176		81	92				0	17
SUM	65618	N.A.	-	-	-	-	-	5	446
AVG	2117	N.A.	80	91	N.A.	N.A.	N.A.	0	14
PFRV	0.7634	N.A.	0.7634	0.7634	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY PERFORMANCE TABLES

JUNE 1985

MONTHLY REPORT: JUNE 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3146

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	108.423 MILLION BTU
	65354 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	42.394 MILLION BTU
	25554 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	87 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.22
ECSS OPERATING ENERGY	0.843 MILLION BTU
STORAGE EFFICIENCY	58.54 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.911 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.188 MILLION BTU
TOTAL ENERGY CONSUMED	46.532 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	25.422	N.A.	N.A.	25.422 MILLION BTU
SOLAR FRACTION	87	N.A.	N.A.	87 PERCENT
SOLAR ENERGY USED	24.165	N.A.	N.A.	24.165 MILLION BTU
OPERATING ENERGY	1.345	N.A.	N.A.	2.188 MILLION BTU
AUX. THERMAL ENERGY	1.257	N.A.	N.A.	1.257 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	1.852	N.A.	N.A.	1.852 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.843 MILLION BTU
FOSSIL SAVINGS	36.067	N.A.	N.A.	36.067 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 2.78

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 55.46

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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MONTHLY REPORT: JUNE 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3146

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	114.386 GIGA JOULES
	742164 KJ/SQ.M.
COLLECTED SOLAR ENERGY	44.726 GIGA JOULES
	290192 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	31 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.22
ECSS OPERATING ENERGY	0.889 GIGA JOULES
STORAGE EFFICIENCY	58.54 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	5.173 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.308 GIGA JOULES
TOTAL ENERGY CONSUMED	49.091 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	26.821	N.A.	N.A.	26.821 GIGA JOULES
SOLAR FRACTION	87	N.A.	N.A.	87 PERCENT
SOLAR ENERGY USED	25.494	N.A.	N.A.	25.494 GIGA JOULES
OPERATING ENERGY	1.419	N.A.	N.A.	2.308 GIGA JOULES
AUX. THERMAL ENG	1.327	N.A.	N.A.	1.327 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	1.954	N.A.	N.A.	1.954 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.889 GIGA JOULES
FOSSIL SAVINGS	38.051	N.A.	N.A.	38.051 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 2.78

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 55.46

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	3.776	80	1.272	N	0.020	N	0.337
2	3.873	81	1.334	O	0.020	O	0.344
3	3.210	78	1.307	T	0.020	T	0.407
4	3.367	73	1.363		0.017		0.405
5	3.604#	85#	0.764#	A	0.025#	A	0.212#
6	3.607#	87#	0.800#	P	0.028#	P	0.222#
7	3.607#	87#	0.800#	P	0.028#	P	0.222#
8	3.607#	87#	0.800#	L	0.028#	L	0.222#
9	3.607#	87#	0.800#	I	0.028#	I	0.222#
10	3.607#	87#	0.800#	C	0.028#	C	0.222#
11	3.607#	87#	0.800#	A	0.028#	A	0.222#
12	3.582	91	0.980	B	0.025	B	0.274
13	3.683	91	1.296	L	0.042	L	0.352
14	3.743	91	1.118	E	0.055	E	0.299
15	3.607#	87#	0.800#		0.028#		0.222#
16	3.607#	87#	0.800#		0.028#		0.222#
17	3.635	93	0.792		0.061		0.218
18	3.665	92	0.807		0.044		0.220
19	3.604#	90#	0.729#		0.025#		0.202#
20	3.607#	87#	0.800#		0.028#		0.222#
21	3.580#	87#	0.744#		0.029#		0.208#
22	3.607#	87#	0.800#		0.028#		0.222#
23	3.607#	87#	0.800#		0.028#		0.222#
24	3.607#	87#	0.800#		0.028#		0.222#
25	3.699	86	0.526		0.024		0.142
26	3.728	86	0.511		0.021		0.137
27	3.699	90	0.403		0.019		0.109
28	3.596	94	0.319		0.019		0.089
29	3.601	92	0.145		0.018		0.040
30	3.489	92	0.154		0.022		0.044
SUM	108.423	-	24.165	N.A.	0.843	N.A.	-
AVG	3.614	87	0.805	N.A.	0.028	N.A.	0.223
PFRV	0.4472	0.4472	0.4444	N.A.	0.4444	N.A.	0.4444

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	3.776	3.036	1.574	90	0.417	0.518
2	3.873	3.093	1.512	89	0.390	0.489
3	3.210	2.347	1.114	89	0.347	0.475
4	3.367	2.634	1.445	82	0.429	0.548
5	3.604#	2.999#	1.459#	99#	0.405#	0.486#
6	3.607#	3.000#	1.415#	99#	0.392#	0.472#
7	3.607#	3.000#	1.415#	99#	0.392#	0.472#
8	3.607#	3.000#	1.415#	99#	0.392#	0.472#
9	3.607#	3.000#	1.415#	99#	0.392#	0.472#
10	3.607#	3.000#	1.415#	99#	0.392#	0.472#
11	3.607#	3.000#	1.415#	99#	0.392#	0.472#
12	3.582	3.052	1.306	87	0.365	0.428
13	3.683	3.375	1.517	110	0.412	0.450
14	3.743	3.742	1.495	105	0.399	0.399
15	3.607#	3.000#	1.415#	99#	0.392#	0.472#
16	3.607#	3.000#	1.415#	99#	0.392#	0.472#
17	3.635	3.635	1.315	106	0.362	0.362
18	3.665	3.266	1.554	103	0.424	0.476
19	3.604#	2.999#	1.459#	99#	0.405#	0.486#
20	3.607#	3.000#	1.415#	99#	0.392#	0.472#
21	3.580#	3.041#	1.390#	102#	0.388#	0.457#
22	3.607#	3.000#	1.415#	99#	0.392#	0.472#
23	3.607#	3.000#	1.415#	99#	0.392#	0.472#
24	3.607#	3.000#	1.415#	99#	0.392#	0.472#
25	3.699	2.963	1.392	97	0.376	0.470
26	3.728	3.038	1.496	99	0.401	0.492
27	3.699	2.874	1.336	108	0.361	0.465
28	3.596	2.600	1.188	110	0.330	0.457
29	3.601	2.635	1.219	102	0.338	0.462
30	3.489	2.826	1.646	103	0.472	0.582
SUM	108.423	90.150	42.394	-	-	-
AVG	3.614	3.005	1.413	99	0.391	0.470
PFRV	0.4472	0.4472	0.4472	0.4472	0.4472	0.4472

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.563	1.272	0.143	143	0.22
2	1.501	1.334	-0.013	147	0.26
3	1.105	1.307	0.134	139	0.52
4	1.436	1.363	0.004	131	0.11
5	1.447#	0.764#	-0.060	148#	1.11#
6	1.402#	0.800#	*	152#	*
7	1.402#	0.800#	*	152#	*
8	1.402#	0.800#	*	152#	*
9	1.402#	0.800#	*	152#	*
10	1.402#	0.800#	*	152#	*
11	1.402#	0.800#	*	152#	*
12	1.295	0.980	-0.675	131	2.26
13	1.501	1.296	0.492	127	0.75
14	1.474	1.118	0.776	140	0.81
15	1.402#	0.800#	*	152#	*
16	1.402#	0.800#	*	152#	*
17	1.290	0.792	0.227	142	0.52
18	1.537	0.807	0.362	145	0.65
19	1.447#	0.729#	-0.003	154#	1.05#
20	1.402#	0.800#	*	152#	*
21	1.376#	0.744#	0.000	153#	0.90#
22	1.402#	0.800#	*	152#	*
23	1.402#	0.800#	*	152#	*
24	1.402#	0.800#	*	152#	*
25	1.380	0.526	-0.215	159	1.35
26	1.483	0.511	0.176	170	0.89
27	1.324	0.403	0.192	177	0.79
28	1.178	0.319	0.287	180	0.62
29	1.205	0.145	-0.064	183	1.15
30	1.634	0.154	-0.272	160	2.42
SUM	41.995	24.165	0.420	-	-
AVG	1.400	0.805	0.014	152	0.91
PFRV	0.4472	0.4444	N.A.	0.4472	0.4472

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

HOT WATER SUBSYSTEM

DAY OF MONTH (NBS ID)	HOT WATER LOAD MILLION BTU (Q302)	SOLAR FR.OF LOAD PER. (N300)	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUP. WAT. TEMP DEG F (N305)	HOT WAT. TEMP DEG F (N307)	HOT WATER USED GAL (N308)
1	1.271	100	1.271	0.041	0.000	N	0.000	N	1.898	81	141	1446
2	1.334	100	1.334	0.041	0.000	O	0.000	O	1.991	82	146	1403
3	1.306	99	1.306	0.047	0.000	T	0.000	T	1.950	81	140	1932
4	1.480	92	1.363	0.043	0.116		0.174		2.034	81	138	2130
5	0.801#	82#	0.764#	0.044#	0.036#	A	0.053#	A	1.140#	83#	124#	1861#
6	0.840#	79#	0.799#	0.044#	0.040#	P	0.059#	P	1.193#	83#	124#	2206#
7	0.840#	79#	0.799#	0.044#	0.040#	P	0.059#	P	1.193#	83#	124#	2206#
8	0.840#	79#	0.799#	0.044#	0.040#	L	0.059#	L	1.193#	83#	124#	2206#
9	0.840#	79#	0.799#	0.044#	0.040#	I	0.059#	I	1.193#	83#	124#	2206#
10	0.840#	79#	0.799#	0.044#	0.040#	C	0.059#	C	1.193#	83#	124#	2206#
11	0.840#	79#	0.799#	0.044#	0.040#	A	0.059#	A	1.193#	83#	124#	2206#
12	1.016	91	0.980	0.057	0.036	B	0.052	B	1.463	83	88	3872
13	1.479	87	1.296	0.054	0.183	L	0.273	L	1.934	83	86	3030
14	1.264	87	1.117	0.048	0.146	E	0.218	E	1.668	83	97	2236
15	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
16	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
17	0.837	94	0.792	0.044	0.045		0.067		1.182	84	121	1880
18	0.889	91	0.806	0.041	0.082		0.122		1.204	83	123	1954
19	0.765#	81#	0.728#	0.044#	0.036#		0.053#		1.087#	83#	124#	1958#
20	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
21	0.786#	79#	0.743#	0.044#	0.042#		0.062#		1.110#	83#	124#	2016#
22	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
23	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
24	0.840#	79#	0.799#	0.044#	0.040#		0.059#		1.193#	83#	124#	2206#
25	0.567	82	0.526	0.043	0.040		0.059		0.785	84	122	1682
26	0.511	100	0.511	0.041	0.000		0.000		0.763	83	123	1759
27	0.403	100	0.403	0.041	0.000		0.000		0.601	84	123	1671
28	0.318	100	0.318	0.041	0.000		0.000		0.475	84	124	1407
29	0.144	100	0.144	0.041	0.000		0.000		0.216	84	123	2814
30	0.154	100	0.154	0.041	0.000		0.000		0.230	84	124	5277
SUM	25.422	-	24.164	1.345	1.257	N.A.	1.851	N.A.	36.067	-	-	66813
AVG	0.847	87	0.805	0.044	0.041	N.A.	0.061	N.A.	1.202	83	121	2227
PFRV	0.4444	0.444	0.4444	0.4444	0.4444	N.A.	0.4472	N.A.	0.4444	0.44	0.44	0.4444

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	1.272	100	0.733	100	1.272	0.042	0.000
2	1.334	100	0.775	100	1.334	0.042	0.000
3	1.307	99	0.945	100	1.307	0.047	0.000
4	1.480	92	1.016	96	1.363	0.044	0.117
5	0.801#	82#	0.564#	96#	0.764#	0.044#	0.037#
6	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
7	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
8	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
9	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
10	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
11	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
12	1.017	91	0.125	92	0.980	0.058	0.036
13	1.479	87	0.061	100	1.296	0.055	0.183
14	1.264	87	0.235	96	1.118	0.049	0.146
15	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
16	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
17	0.838	94	0.588	98	0.792	0.044	0.045
18	0.889	91	0.636	94	0.807	0.042	0.082
19	0.766#	81#	0.592#	97#	0.729#	0.044#	0.037#
20	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
21	0.787#	79#	0.601#	97#	0.744#	0.044#	0.043#
22	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
23	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
24	0.841#	79#	0.666#	97#	0.800#	0.045#	0.041#
25	0.567	82	0.523	96	0.526	0.044	0.041
26	0.511	100	0.582	100	0.511	0.042	0.000
27	0.403	100	0.549	100	0.403	0.042	0.000
28	0.319	100	0.463	100	0.319	0.042	0.000
29	0.145	100	0.918	100	0.145	0.042	0.000
30	0.154	100	1.737	100	0.154	0.042	0.000
SUM	25.422	-	19.636	-	24.165	1.345	1.257
AVG	0.847	87	0.655	98	0.805	0.045	0.042
PFRV	0.4444	0.4444	0.4444	0.4444	0.4444	0.4444	0.4444

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MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.000	N	1.898	81	141	1446	1446	N
2	O	0.000	O	1.991	82	146	1403	1403	O
3	T	0.000	T	1.950	81	140	1933	1933	T
4		0.175		2.035	81	138	2131	2131	
5	A	0.054#	A	1.141#	83#	124#	1861#	1861#	A
6	P	0.059#	P	1.194#	83#	124#	2206#	2206#	P
7	P	0.059#	P	1.194#	83#	124#	2206#	2206#	P
8	L	0.059#	L	1.194#	83#	124#	2206#	2206#	L
9	I	0.059#	I	1.194#	83#	124#	2206#	2206#	I
10	C	0.059#	C	1.194#	83#	124#	2206#	2206#	C
11	A	0.059#	A	1.194#	83#	124#	2206#	2206#	A
12	B	0.053	B	1.463	83	88	3872	3872	B
13	L	0.273	L	1.934	83	86	3030	3030	L
14	E	0.219	E	1.668	83	97	2236	2236	E
15		0.059#		1.194#	83#	124#	2206#	2206#	
16		0.059#		1.194#	83#	124#	2206#	2206#	
17		0.068		1.183	84	121	1881	1881	
18		0.123		1.204	83	123	1955	1955	
19		0.054#		1.088#	83#	124#	1959#	1959#	
20		0.059#		1.194#	83#	124#	2206#	2206#	
21		0.063#		1.110#	83#	124#	2016#	2016#	
22		0.059#		1.194#	83#	124#	2206#	2206#	
23		0.059#		1.194#	83#	124#	2206#	2206#	
24		0.059#		1.194#	83#	124#	2206#	2206#	
25		0.059		0.786	84	122	1683	1683	
26		0.000		0.763	83	123	1759	1759	
27		0.000		0.602	84	123	1671	1671	
28		0.000		0.476	84	124	1407	1407	
29		0.000		0.216	84	123	2815	2815	
30		0.000		0.231	84	124	5278	5278	
SUM	N.A.	1.852	N.A.	36.067	-	-	66814	66814	N.A.
AVG	N.A.	0.062	N.A.	1.202	83	121	2227	2227	N.A.
PFRV	N.A.	0.4472	N.A.	0.4444	0.4444	0.4444	0.4444	0.4444	N.A.

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MONTHLY REPORT: TUCSON JOB CORPS - P-3146 JUNE 1985

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	2276	N	80	90	N	N	N	0	15
2	2335	O	81	89	O	O	O	0	14
3	1935	T	78	89	T	T	T	0	12
4	2030		73	82				0	9
5	2173#	A	85#	99#	A	A	A	1	0
6	2174#	P	87#	99#	P	P	P	*	*
7	2174#	P	87#	99#	P	P	P	*	*
8	2174#	L	87#	99#	L	L	L	*	*
9	2174#	I	87#	99#	I	I	I	*	*
10	2174#	C	87#	99#	C	C	C	*	*
11	2174#	A	87#	99#	A	A	A	*	*
12	2159	B	91	87	B	B	B	0	32
13	2220	L	91	110	L	L	L	0	26
14	2256	E	91	105	E	E	E	0	27
15	2174#		87#	99#				*	*
16	2174#		87#	99#				*	*
17	2191		93	106				0	26
18	2209		92	103				0	25
19	2173#		90#	99#				0	14
20	2174#		87#	99#				*	*
21	2158#		87#	102#				0	28
22	2174#		87#	99#				*	*
23	2174#		87#	99#				*	*
24	2174#		87#	99#				*	*
25	2229		86	97				0	25
26	2247		86	99				0	21
27	2229		90	108				0	25
28	2167		94	110				0	29
29	2170		92	102				0	23
30	2103		92	103				0	24
SUM	65354	N.A.	-	-	-	-	-	1	627
AVG	2178	N.A.	87	99	N.A.	N.A.	N.A.	0	21
PFRV	0.4472	N.A.	0.4472	0.4472	N.A.	N.A.	N.A.	N.A.	N.A.

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MONTHLY PERFORMANCE TABLES

JULY 1985

MONTHLY REPORT: JULY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3146R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	100.683 MILLION BTU
	60689 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	41.810 MILLION BTU
	25202 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	89 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.16
ECSS OPERATING ENERGY	1.563 MILLION BTU
STORAGE EFFICIENCY	36.85 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	1.284 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	3.137 MILLION BTU
TOTAL ENERGY CONSUMED	44.947 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	15.670	N.A.	N.A.	15.670 MILLION BTU
SOLAR FRACTION	100	N.A.	N.A.	100 PERCENT
SOLAR ENERGY USED	15.670	N.A.	N.A.	15.670 MILLION BTU
OPERATING ENERGY	1.574	N.A.	N.A.	3.137 MILLION BTU
AUX. THERMAL ENERGY	0.000	N.A.	N.A.	0.000 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	0.000	N.A.	N.A.	0.000 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.563 MILLION BTU
FOSSIL SAVINGS	23.389	N.A.	N.A.	23.389 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.50

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.00

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: JULY 1985
SITE SUMMARY: TUCSON JOB CORPS - P-3146R

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	106.221 GIGA JOULES
	689188 KJ/SQ.M.
COLLECTED SOLAR ENERGY	44.109 GIGA JOULES
	286194 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	32 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.16
ECSS OPERATING ENERGY	1.649 GIGA JOULES
STORAGE EFFICIENCY	36.85 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	7.291 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	3.309 GIGA JOULES
TOTAL ENERGY CONSUMED	47.419 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	16.532	N.A.	N.A.	16.532 GIGA JOULES
SOLAR FRACTION	100	N.A.	N.A.	100 PERCENT
SOLAR ENERGY USED	16.532	N.A.	N.A.	16.532 GIGA JOULES
OPERATING ENERGY	1.660	N.A.	N.A.	3.309 GIGA JOULES
AUX. THERMAL ENG	0.000	N.A.	N.A.	0.000 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	0.000	N.A.	N.A.	0.000 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.649 GIGA JOULES
FOSSIL SAVINGS	24.675	N.A.	N.A.	24.675 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.50

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.00

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: TUCSON JOB CORPS - P-3146R JULY 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	3.604	92	0.385	N	0.022	N	0.107
2	3.605	94	0.188	O	0.021	O	0.052
3	3.578	98	0.097	T	0.022	T	0.027
4	3.578	94	0.046		0.017		0.013
5	3.492	93	0.000	A	0.015	A	0.000
6	3.413	90	0.000	P	0.032	P	0.000
7	3.384	93	0.005	P	0.067	P	0.002
8	3.349	96	0.565	L	0.067	L	0.169
9	3.551	92	0.747	I	0.067	I	0.210
10	3.577	91	0.668	C	0.066	C	0.187
11	3.585	94	0.689	A	0.067	A	0.192
12	3.496	98	0.612	B	0.044	B	0.175
13	3.312	95	0.287	L	0.020	L	0.087
14	3.446	90	0.259	E	0.021	E	0.075
15	3.398	85	0.278		0.020		0.082
16	2.679	84	0.384		0.017		0.143
17	2.860	81	0.472		0.043		0.165
18	2.472	79	0.670		0.067		0.271
19	2.314	78	0.562		0.067		0.243
20	3.640	85	0.832		0.067		0.229
21	2.511	82	0.850		0.067		0.338
22	3.485	87	0.757		0.067		0.217
23	3.569	87	0.829		0.067		0.232
24	3.637	88	0.675		0.067		0.185
25	3.727	86	0.748		0.067		0.201
26	3.538	91	0.681		0.066		0.192
27	2.278	85	0.590		0.067		0.259
28	1.771	81	0.606		0.067		0.342
29	3.443	88	0.758		0.067		0.220
30	3.631	91	0.826		0.066		0.228
31	2.759	87	0.604		0.065		0.219
SUM	100.683	-	15.670	N.A.	1.563	N.A.	-
AVG	3.248	89	0.505	N.A.	0.050	N.A.	0.156
PFRV	1.0000	1.0000	1.0000	N.A.	1.0000	N.A.	1.0000

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MONTHLY REPORT: TUCSON JOB CORPS - P-3146R JULY 1985

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	3.604	2.956	1.561	106	0.433	0.528
2	3.605	2.897	1.436	108	0.398	0.496
3	3.578	2.951	1.336	108	0.373	0.453
4	3.578	2.576	1.283	100	0.358	0.498
5	3.492	2.131	0.977	102	0.280	0.458
6	3.413	2.141	0.881	105	0.258	0.412
7	3.384	3.384	1.133	104	0.335	0.335
8	3.349	3.349	1.251	109	0.373	0.373
9	3.551	3.551	1.430	103	0.403	0.403
10	3.577	3.577	1.458	100	0.408	0.408
11	3.585	3.585	1.532	104	0.427	0.427
12	3.496	3.118	1.641	111	0.469	0.526
13	3.312	2.573	1.438	103	0.434	0.559
14	3.446	2.818	1.466	98	0.425	0.520
15	3.398	2.714	1.309	97	0.385	0.482
16	2.679	2.165	1.137	100	0.424	0.525
17	2.860	2.740	0.962	90	0.336	0.351
18	2.472	2.472	1.005	85	0.407	0.407
19	2.314	2.314	1.055	88	0.456	0.456
20	3.640	3.640	1.802	94	0.495	0.495
21	2.511	2.511	1.090	93	0.434	0.434
22	3.485	3.485	1.742	95	0.500	0.500
23	3.569	3.569	1.607	97	0.450	0.450
24	3.637	3.637	1.572	96	0.432	0.432
25	3.727	3.727	1.576	95	0.423	0.423
26	3.538	3.538	1.659	106	0.469	0.469
27	2.278	2.278	0.915	97	0.401	0.401
28	1.771	1.771	1.009	88	0.570	0.570
29	3.443	3.443	1.837	100	0.534	0.534
30	3.631	3.631	1.579	102	0.435	0.435
31	2.759	2.650	1.133	100	0.411	0.428
SUM	100.683	91.891	41.810	-	-	-
AVG	3.248	2.964	1.349	100	0.415	0.455
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: TUCSON JOB CORPS - P-3146R JULY 1985

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.549	0.385	0.279	158	1.25
2	1.424	0.188	0.300	172	1.12
3	1.322	0.097	0.158	179	1.23
4	1.270	0.046	0.265	182	1.02
5	0.966	0.000	0.068	190	0.87
6	0.853	0.000	-0.863	180	1.78
7	1.092	0.005	0.024	149	1.78
8	1.215	0.565	-0.038	144	1.32
9	1.393	0.747	0.011	143	1.18
10	1.421	0.668	0.093	141	1.25
11	1.495	0.689	0.069	142	1.42
12	1.621	0.612	0.403	148	1.15
13	1.426	0.287	0.352	164	1.07
14	1.450	0.259	0.190	172	1.14
15	1.294	0.278	0.292	176	0.75
16	1.125	0.384	-0.454	174	1.24
17	0.933	0.472	-0.506	155	1.22
18	0.976	0.670	-0.206	123	1.08
19	1.028	0.562	-0.055	116	1.28
20	1.775	0.832	0.335	125	1.41
21	1.062	0.850	-0.223	125	0.96
22	1.715	0.757	0.315	126	1.52
23	1.576	0.829	0.076	134	1.33
24	1.541	0.675	0.130	137	1.41
25	1.544	0.748	0.023	138	1.41
26	1.629	0.681	0.144	138	1.60
27	0.886	0.590	-0.298	129	1.26
28	0.989	0.606	-0.143	111	1.65
29	1.813	0.758	0.453	125	1.55
30	1.551	0.826	0.149	136	1.19
31	1.104	0.604	-0.162	133	1.35
SUM	41.038	15.670	-0.550	-	-
AVG	1.324	0.505	-0.018	147	1.28
PFRV	1.0000	1.0000	N.A.	1.0000	1.0000

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HOT WATER SUBSYSTEM

DAY OF MONTH (NBS ID)	HOT WATER LOAD MILLION BTU (Q302)	SOLAR FR.OF LOAD PER. (N300)	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUP. WAT. TEMP DEG F (N305)	HOT WAT. TEMP DEG F (N307)	HOT WATER USED GAL (N308)
1	0.385	100	0.385	0.041	0.000	N	0.000	N	0.575	84	122	2962
2	0.188	100	0.188	0.041	0.000	O	0.000	O	0.281	84	122	1446
3	0.096	100	0.096	0.041	0.000	T	0.000	T	0.144	84	123	1632
4	0.045	100	0.045	0.041	0.000		0.000		0.068	84	125	1055
5	0.000	0	0.000	0.041	0.000	A	0.000	A	0.000	85	125	732
6	0.000	0	0.000	0.041	0.000	P	0.000	P	0.000	85	125	889
7	0.005	100	0.005	0.041	0.000	P	0.000	P	0.007	85	125	840
8	0.565	100	0.565	0.041	0.000	L	0.000	L	0.843	85	124	1231
9	0.746	100	0.746	0.048	0.000	I	0.000	I	1.114	84	117	1935
10	0.668	100	0.668	0.050	0.000	C	0.000	C	0.997	84	124	1329
11	0.689	100	0.689	0.049	0.000	A	0.000	A	1.029	84	123	1465
12	0.611	100	0.611	0.047	0.000	B	0.000	B	0.913	85	122	1280
13	0.286	100	0.286	0.041	0.000	L	0.000	L	0.427	85	124	1074
14	0.258	100	0.258	0.041	0.000	E	0.000	E	0.385	85	125	1123
15	0.278	100	0.278	0.041	0.000		0.000		0.415	85	123	1112
16	0.383	100	0.383	0.041	0.000		0.000		0.572	85	124	1671
17	0.471	100	0.471	0.041	0.000		0.000		0.703	84	124	2075
18	0.669	100	0.669	0.056	0.000		0.000		0.999	83	121	1798
19	0.562	100	0.562	0.071	0.000		0.000		0.839	82	107	1577
20	0.832	100	0.832	0.065	0.000		0.000		1.242	83	109	1954
21	0.849	100	0.849	0.055	0.000		0.000		1.268	84	118	1964
22	0.756	100	0.756	0.065	0.000		0.000		1.129	83	108	1798
23	0.828	100	0.828	0.054	0.000		0.000		1.237	83	119	1769
24	0.674	100	0.674	0.053	0.000		0.000		1.006	82	120	1446
25	0.748	100	0.748	0.052	0.000		0.000		1.116	83	122	1622
26	0.680	100	0.680	0.053	0.000		0.000		1.016	83	120	1622
27	0.590	100	0.590	0.048	0.000		0.000		0.881	84	120	1123
28	0.605	100	0.605	0.081	0.000		0.000		0.904	84	108	2179
29	0.758	100	0.758	0.068	0.000		0.000		1.132	83	109	2414
30	0.826	100	0.826	0.054	0.000		0.000		1.233	83	119	2327
31	0.603	100	0.603	0.052	0.000		0.000		0.900	83	122	2238
SUM	15.670	-	15.670	1.573	0.000	N.A.	0.000	N.A.	23.389	-	-	49696
AVG	0.505	100	0.505	0.050	0.000	N.A.	0.000	N.A.	0.754	84	119	1603
PFRV	1.0000	1.000	1.0000	1.0000	1.0000	N.A.	1.0000	N.A.	1.0000	1.00	1.00	1.0000

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

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HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	0.385	100	0.933	100	0.385	0.042	0.000
2	0.188	100	0.463	100	0.188	0.042	0.000
3	0.097	100	0.524	100	0.097	0.042	0.000
4	0.046	100	0.352	100	0.046	0.042	0.000
5	0.000	0	0.245	100	0.000	0.042	0.000
6	0.000	0	0.302	100	0.000	0.042	0.000
7	0.005	100	0.278	100	0.005	0.042	0.000
8	0.565	100	0.397	100	0.565	0.042	0.000
9	0.747	100	0.527	100	0.747	0.048	0.000
10	0.668	100	0.434	100	0.668	0.051	0.000
11	0.689	100	0.477	100	0.689	0.050	0.000
12	0.612	100	0.402	100	0.612	0.047	0.000
13	0.287	100	0.346	100	0.287	0.042	0.000
14	0.259	100	0.367	100	0.259	0.042	0.000
15	0.278	100	0.354	100	0.278	0.042	0.000
16	0.384	100	0.539	100	0.384	0.042	0.000
17	0.472	100	0.685	100	0.472	0.042	0.000
18	0.670	100	0.563	100	0.670	0.057	0.000
19	0.562	100	0.321	100	0.562	0.071	0.000
20	0.832	100	0.410	100	0.832	0.065	0.000
21	0.850	100	0.560	100	0.850	0.056	0.000
22	0.757	100	0.372	100	0.757	0.066	0.000
23	0.829	100	0.529	100	0.829	0.054	0.000
24	0.675	100	0.448	100	0.675	0.053	0.000
25	0.748	100	0.527	100	0.748	0.053	0.000
26	0.681	100	0.502	100	0.681	0.053	0.000
27	0.590	100	0.331	100	0.590	0.049	0.000
28	0.606	100	0.435	100	0.606	0.082	0.000
29	0.758	100	0.517	100	0.758	0.068	0.000
30	0.826	100	0.697	100	0.826	0.054	0.000
31	0.604	100	0.710	100	0.604	0.052	0.000
SUM	15.670	-	14.545	-	15.670	1.574	0.000
AVG	0.505	100	0.469	100	0.505	0.051	0.000
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* UNAVAILABLE: N.A. NOT APPLICABLE: I INVALID: E ESTIMATED: # <60% VALID DATA: PFRV RELIABILITY VALUE

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HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.000	N	0.575	84	122	2962	2962	N
2	O	0.000	O	0.281	84	122	1446	1446	O
3	T	0.000	T	0.145	84	123	1632	1632	T
4		0.000		0.068	84	125	1056	1056	
5	A	0.000	A	0.000	85	125	733	733	A
6	P	0.000	P	0.000	85	125	889	889	P
7	P	0.000	P	0.008	85	125	841	841	P
8	L	0.000	L	0.844	85	124	1232	1232	L
9	I	0.000	I	1.115	84	117	1935	1935	I
10	C	0.000	C	0.998	84	124	1329	1329	C
11	A	0.000	A	1.029	84	123	1466	1466	A
12	B	0.000	B	0.913	85	122	1280	1280	B
13	L	0.000	L	0.428	85	124	1075	1075	L
14	E	0.000	E	0.386	85	125	1124	1124	E
15		0.000		0.415	85	123	1113	1113	
16		0.000		0.573	85	124	1671	1671	
17		0.000		0.704	84	124	2075	2075	
18		0.000		1.000	83	121	1798	1798	
19		0.000		0.839	82	107	1578	1578	
20		0.000		1.242	83	109	1955	1955	
21		0.000		1.268	84	118	1964	1964	
22		0.000		1.129	83	108	1798	1798	
23		0.000		1.237	83	119	1769	1769	
24		0.000		1.007	82	120	1446	1446	
25		0.000		1.116	83	122	1622	1622	
26		0.000		1.016	83	120	1622	1622	
27		0.000		0.881	84	120	1124	1124	
28		0.000		0.904	84	108	2179	2179	
29		0.000		1.132	83	109	2414	2414	
30		0.000		1.233	83	119	2328	2328	
31		0.000		0.901	83	122	2238	2238	
SUM	N.A.	0.000	N.A.	23.389	-	-	49696	49696	N.A.
AVG	N.A.	0.000	N.A.	0.754	84	119	1603	1603	N.A.
PFRV	N.A.	1.0000	N.A.	1.0000	1.0000	1.0000	1.0000	1.0000	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

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ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	2173	N	92	106	N	N	N	0	24
2	2173	O	94	108	O	O	O	0	26
3	2157	T	98	108	T	T	T	0	36
4	2157		94	100				0	27
5	2105	A	93	102	A	A	A	0	27
6	2057	P	90	105	P	P	P	0	27
7	2040	P	93	104	P	P	P	0	29
8	2019	L	96	109	L	L	L	0	31
9	2141	I	92	103	I	I	I	0	28
10	2156	C	91	100	C	C	C	0	25
11	2161	A	94	104	A	A	A	0	28
12	2107	B	98	111	B	B	B	0	34
13	1997	L	95	103	L	L	L	0	29
14	2077	E	90	98	E	E	E	0	23
15	2048		85	97				0	23
16	1615		84	100				0	25
17	1724		81	90				0	17
18	1490		79	85				0	15
19	1395		78	88				0	18
20	2194		85	94				0	20
21	1514		82	93				0	20
22	2101		87	95				0	23
23	2152		87	97				0	21
24	2192		88	96				0	22
25	2246		86	95				0	20
26	2132		91	106				0	27
27	1373		85	97				0	26
28	1067		81	88				0	17
29	2075		88	100				0	25
30	2189		91	102				0	27
31	1663		87	100				0	24
SUM	60689	N.A.	-	-	-	-	-	0	765
AVG	1958	N.A.	89	100	N.A.	N.A.	N.A.	0	25
PFRV	1.0000	N.A.	1.0000	1.0000	N.A.	N.A.	N.A.	N.A.	N.A.

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

APPENDIX F

F-CHART INPUT PARAMETERS

APPENDIX F

F-CHART INPUT PARAMETERS

Two F-Chart runs have been made in the evaluation of this solar system. The first F-Chart run as discussed in Section IV of this report was made to determine the expected system performance of the system in its "as built" configuration based on data collected by ETEC at the time of the system acceptance test. Due to limited funding it was not possible to monitor the system for a full year. A second F-Chart run was made to "extrapolate" annual performance data from the measured data collected during the monitored period. The results of these two F-Chart runs are compared in Section V.

The following rationale was used in choosing the input parameters used in each F-Chart run:

1. In general, the "predicted" cases were based on the solar system operating parameters obtained at the time of the Acceptance Test. The ASHRAE single panel collector test results were used for the F-chart predicted runs. However, the collector flow rate/area, the load and weather data used in the "measured or extrapolated" cases were also used in the "predicted" cases. This was done to put the "predicted" and "extrapolated" cases on a comparable basis.

2. The "extrapolated" cases were based on measured long-term solar system operating parameters data.

3. In both the "predicted" and "extrapolated" cases, the measured/extrapolated loads were obtained from long-term monitoring. Data for months not measured was estimated from measured months.

4. Since F-Chart Version 5.5 only accepts horizontal data as an input, the measured insolation in the plane of the collector had to be converted to horizontal values. Since the algorithm used in F-chart to convert the horizontal data to the plane of the collector was unknown, several iterations of F-chart were required to adjust the input data so that the F-chart output value of monthly isolation in the plane of the collector equalled the measured values. For the months in which insolation was not measured, the long-term monthly-averaged daily insolation supplied by F-Chart was used.

5. Since the uncertainty is high for immersion heat exchanger effectiveness measured during the acceptance test, values determined from monitoring data, were used for both the "predicted" and "extrapolated" cases. For external heat exchangers, the heat exchanger effectiveness based on acceptance test data was used for the "predicted" cases, whereas the monitored heat exchanger effectiveness was used for the "extrapolated" case.

6. For the "extrapolated" cases, monitored collector efficiency curves with no incidence angle modifiers were used because the efficiency curves represent an average of the all-day performance including the effect of the incident angle modifier. For "predicted" cases, manufacturer's information was used for the efficiency and incidence angle modifiers.

7. Piping heat loss coefficient area (UA) products were calculated based on estimated piping length and insulation thickness.

8. The storage UA was calculated based on the tank surface area and an estimated insulation thickness for the "predicted" cases. The values for the "extrapolated" cases were derived from monitored data.

9. Since the F-Chart program is limited in the types of systems which it can model, it was often necessary to adjust the input parameters to adequately model a particular system. Five main problem areas were encountered: 1) cooling systems could not be directly modeled, 2) in certain cases, system configurations deviated from those available in F-Chart, 3) the storage capacities of the Quality Sites occasionally fell outside of the range allowed by F-Chart DHW systems. 4) The F-Chart water storage model does not properly account for the load side recirculation losses 5) The hot water load profile used in the water storage model is not representative of the large SFBP systems. These problems were resolved as follows: 1) cooling systems were modeled as though the absorption chiller was a process hot water load. 2) The available F-Chart system configuration which best fit the actual system was used. 3) For the large hot water systems the general solar heating model was used to permit inclusion of the load side recirculation losses as part of the load. The load profile used in the general solar heating model also appears to match the SFBP hot water system more closely. 4) When the water storage model was used, the total storage capacity was maintained by assigning the maximum allowable storage volume to the solar portion of F-Chart and assigning the remaining storage volume to the auxiliary DHW system. 5) If the general solar heating model was used for a hot water system, losses from the preheat tank were added to the UA of the solar storage tank to ensure all storage losses were considered. The preheat tank volume was included as part of the solar storage volume if there was no heat exchanger between the two tanks, but not when there was a heat exchanger between the two tanks because the low heat exchanger effectiveness values observed reduced the usefulness of the preheat tank for storage of solar energy.

10. For Tucson, the water storage type of F-chart was used because the general solar heating system would not compute. In order to equate the DHW load to measured quantities, it was necessary to increase the auxiliary tank UA to 180 and manipulate the environmental temperatures. The change in environmental temperature was observed to have no effect on the solar collector.

Table F-1. F-CHART PREDICTED INPUT PARAMETERS

TUCSON

	** FLAT PLATE COLLECTOR **		
1	NUMBER OF COLLECTOR PANELS....	79	
2	COLLECTOR PANEL AREA..........	22.5	FT2
3	FR*UL (TEST SLOPE)............	.695	BTU/HR-FT2-F
4	FR*TAU*ALPHA (TEST INTERCEPT).	.657	
5	COLLECTOR SLOPE...............	30	DEG
6	COLLECTOR AZIMUTH (SOUTH=0)...	0	DEG
7	INCIDENCE ANGLE MOD TYPE(8-10)	9	
8	NUMBER OF GLAZINGS..........	2	
9	INC ANGLE MODIFIER CONSTANT.	.08	
10	INC ANGLE MODIFIER VALUE(S).		
	1 .999 .998 .995 .981 .953 .882		
	.7 .35 0		
11	COLLECTOR FLOWRATE/AREA.......	15.2	LB/HR-FT2
12	COLLECTOR FLUID SPECIFIC HEAT.	1	BTU/LB-F
13	MODIFY TEST VALUES (1=Y,2=N)..	1	
14	TEST COLLECTOR FLOWRATE/AREA	28.7	LB/HR-FT2
15	TEST FLUID SPECIFIC HEAT....	.764	BTU/LB-F
	*** WATER STORAGE SYSTEM ***		
1	CITY CALL NUMBER..............	215	
2	WATER STORAGE VOLUME..........	2200	GALLONS
3	BUILDING UA (0 FOR DHW ONLY)..	0	BTU/HR-F
4	FUEL (1=EL,2=NG,3=OIL,4=OTHER)	2	
5	EFFICIENCY OF FUEL USAGE......	60	%
6	DOMESTIC HOT WATER (1=Y,2=N)..	1	
7	DAILY HOT WATER USAGE.......		GALLONS
	2419 3017 2689 2440 1898 2230		
	1605 1605 2300 2575 2875 2130		
8	WATER SET TEMPERATURE.......		F
	125 129 132 136 139 124 123 124		
	120 118 129 105		
9	ENVIRONMENT TEMPERATURE.....		F
	50 67 47.6 49.6 35.2 46.8 69.2		
	52.3 48.3 100.8 103.5 33.3		
10	DHW STORAGE TANK SIZE.......	1645	GALLONS
11	UA OF AUX STORAGE TANK......	180	BTU/HR-F
12	PIPE HEAT LOSS (1=Y,2=N)......	1	
13	INLET PIPE UA...............	12	BTU/HR-F
14	OUTLET PIPE UA..............	11.9	BTU/HR-F
15	RELATIVE LOAD HX SIZE.........	1	
16	COLLECTOR-STORAGE HX (1=Y,2=N)	2	
17	TANK SIDE FLOWRATE/AREA.....	11	LB/HR-FT2
18	HEAT EXCHANGER EFFECTIVENESS	.5	

Table F-1. F-CHART PREDICTED INPUT PARAMETERS (Continued)

TUCSON

TUCSON AZ LAT= 32.1

DEGREE-DAY BASE TEMPERATURE= 65 F

	SOLAR BTU/FT2	TEMP F	DEGDAY F-DAYS	MAINS F	REFLEC	HUMID LB/LB
JAN	1060	50.0	444	70.0	.20	.0038
FEB	1431	53.4	333	70.0	.20	.0034
MAR	1594	60.0	254	73.0	.20	.0034
APR	1957	72.0	77	77.0	.20	.0030
MAY	2143	80.0	11	79.0	.20	.0032
JUN	2273	87.0	0	83.0	.20	.0049
JUL	2016	89.0	0	84.0	.20	.0108
AUG	2139	83.8	0	84.0	.20	.0120
SEP	1939	80.1	1	82.0	.20	.0091
OCT	1328	70.2	28	80.0	.20	.0054
NOV	1031	53.0	221	73.0	.20	.0041
DEC	1047	52.0	412	71.0	.20	.0038

Table F-2. F-CHART EXTRAPOLATED INPUT PARAMETERS

TUCSON

1	NUMBER OF COLLECTOR PANELS....	79	
2	COLLECTOR PANEL AREA..........	22.5	FT2
3	FR*UL (TEST SLOPE)............	.648	BTU/HR-FT2-F
4	FR*TAU*ALPHA (TEST INTERCEPT).	.654	
5	COLLECTOR SLOPE...............	30	DEG
6	COLLECTOR AZIMUTH (SOUTH=0)...	0	DEG
7	RECEIVER ORIENT (1=EW,2=NS)...	9	
8	INC ANGLE MOD (PERPENDICULAR).	2	
9	INC ANGLE MOD (PARALLEL)......	0	
10	COLLECTOR FLOWRATE/AREA.......		LB/HR-FT2
	1 .999 .998 .995 .981 .953 .882		
	.7 .35 0		
11	COLLECTOR FLUID SPECIFIC HEAT.	15.2	BTU/LB-F
12	MODIFY TEST VALUES (1=Y,2=N)..	2	
13	TEST COLLECTOR FLOWRATE/AREA	2	LB/HR-FT2
14	TEST FLUID SPECIFIC HEAT....	11	BTU/LB-F
15	TEST FLUID SPECIFIC HEAT....	1	BTU/LB-F
	*** WATER STORAGE SYSTEM ***		
1	CITY CALL NUMBER..............	215	
2	WATER STORAGE VOLUME..........	2200	GALLONS
3	BUILDING UA (0 FOR DHW ONLY)..	0	BTU/HR-F
4	FUEL (1=EL,2=NG,3=OIL,4=OTHER)	2	
5	EFFICIENCY OF FUEL USAGE......	60	%
6	DOMESTIC HOT WATER (1=Y,2=N)..	1	
7	DAILY HOT WATER USAGE.......		GALLONS
	2419 3017 2689 2440 1898 2230		
	1605 1605 2300 2575 2875 2130		
8	WATER SET TEMPERATURE.......		F
	125 129 132 136 139 124 123 124		
	120 118 129 105		
9	ENVIRONMENT TEMPERATURE.....		F
	50 67 47.6 49.6 35.2 46.8 69.2		
	52.3 48.3 100.8 103.5 33.3		
10	DHW STORAGE TANK SIZE.......	1645	GALLONS
11	UA OF AUX STORAGE TANK......	180	BTU/HR-F
12	PIPE HEAT LOSS (1=Y,2=N)......	1	
13	INLET PIPE UA...............	12	BTU/HR-F
14	OUTLET PIPE UA..............	11.9	BTU/HR-F
15	RELATIVE LOAD HX SIZE.........	1	
16	COLLECTOR-STORAGE HX (1=Y,2=N)	2	
17	TANK SIDE FLOWRATE/AREA.....	11	LB/HR-FT2
18	HEAT EXCHANGER EFFECTIVENESS	.5	

Table F-2. F-CHART EXTRAPOLATED INPUT PARAMETERS (Continued)

TUCSON

TUCSON AZ LAT= 32.1

DEGREE-DAY BASE TEMPERATURE= 65 F

	SOLAR BTU/FT2	TEMP F	DEGDAY F-DAYS	MAINS F	REFLEC	HUMID LB/LB
JAN	1060	50.0	444	70.0	.20	.0038
FEB	1431	53.4	333	70.0	.20	.0034
MAR	1594	60.0	254	73.0	.20	.0034
APR	1957	72.0	77	77.0	.20	.0030
MAY	2143	80.0	11	79.0	.20	.0032
JUN	2273	87.0	0	83.0	.20	.0049
JUL	2016	89.0	0	84.0	.20	.0108
AUG	2139	83.8	0	84.0	.20	.0120
SEP	1939	80.1	1	82.0	.20	.0091
OCT	1328	70.2	28	80.0	.20	.0054
NOV	1031	53.0	221	73.0	.20	.0041
DEC	1047	52.0	412	71.0	.20	.0038

APPENDIX G

CONTROL STRATEGY TESTS

APPENDIX G

CONTROL STRATEGY TESTS

Tests were performed at the Tucson Job Corps Center to determine if there was any solar energy collection improvement when the collector control was changed from a temperature difference of 20°F on and 5°F off to 5°F on and 1°F off and to quantify the improvement.

The test was run between October 17 and 30, 1985. The control set points were manually adjusted to approximately 5°F on and 1°F off on October 17, 1985. The control set point was changed to 20°F on and 5°F off on October 23, 1985. The control set point was monitored by two RTD temperature sensors located adjacent to the control sensors. One RTD was positioned on the outlet manifold of the sixth panel from the West end of the array. The other RTD was fastened to the storage tank surface near the tank bottom. The collector performance was measured by the usual SFBP flow ΔT measurement suite.

The results of the control set point monitoring are listed in Table G-1 and G-2.

Table G-1. MEASURED CONDITIONS WITH CONTROL SET POINTS OF 5°F ON AND 1°F OFF

	Startup		Shutdown	
Date	Insolation	ΔT	Insolation	ΔT
10/17	135.8	8.0	14.7	-2.8
	67.0	6.5	37.6	-2.2
	58.9	4.5	-	-
10/18	126	5.9	101.4	-5.3
10/19	117.8	3.9	62.1	0.0
10/20	108	2.5	89.9	-5.1
10/21	127.6	-8.0	62.2	-2.3
10/22	153.7	-4.6	160.3	-3.1
Average	111.9	2.3	75.5	-3.0

From Table G-1, the average starting point was 2.3°F and the average shutdown point was -3.0°F. Though the average shutdown point was -3.0°F, the collector temperature difference always remained slightly (about 1°F) positive. In Table G-2, the average starting point was 20.1°F and the average shutdown point was 4.4°F.

Table G-1. MEASURED CONDITIONS WITH CONTROL SET POINTS OF 20°F ON AND 5°F OFF

Date	Insolation	ΔT	Insolation	ΔT
10/23	-	-	269.9	6.4
10/24	124.0	21.4	184.8	6.2
	148.6	21.0	-	-
10/25	127.6	>30.0 (not used average)	153.7	2.5
10/26	116.1	19.5	124.3	4.5
	-	-	72.0	2.7
10/27	165.2	18.8	140.6	6.0
10/28	107.9	20.5	78.5	3.8
10/29	157.0	13.3	166.8	2.7
10/30	163.5	26.5	-	-
Average	138.7	20.1	148.8	4.4

To determine the improvement in collector performance, the measured data was run through the Tucson SFBP Solar collector Computer code.

The important numbers generated by the computer analysis are shown in Table G-3.

Table G-3. SYSTEM PERFORMANCE

(All values in million BTU, unless otherwise indicated)

Set Point	Total Solar Insolation	Solar Energy Collected	Solar Collector Efficiency (%)	Operational Solar Insolation	Operational Collector Efficiency (%)
5°F On, 1°F Off	15.4	7.43	48	13.3	56
20°F On, 5°F Off	21.9	11.7	53	18.2	64

On the basis of the numbers presented in Table G-3, it would appear that the 20°F on, 5°F off set point performed better but there was significantly better insolation during the 20°F on, 5°F off monitoring period. If one takes the ratio of Operaional Insolation to Total Insolation for the 5°F on, 1°F off case, this was 0.865. The same ratio was 0.828 for the 20°F on, 5°F off case. Therefore, the collector system ran longer with the 5°F on, 1°F off set point. Applying the 0.865 ratio of operational to total insolation to the 20°F on, 5°F off case yields an increased operational insolation availability of 0.8 million BTU. Assuming a collection efficiency of 56% results in 0.45 million BTU additional energy collected or 3.8% improvement. Alternatively, assuming a 64% collection efficiency results in 0.51 million BTU additional energy collected or 4.3% improvement.

As a check on the preceding calculations, the extra energy collected was determined directly from the measurements using the insolation threshold for the 20°F on, 5°F off case. The insolation threshold for 20°F on was 138.7 BTU/ft^2-hr and the insolation threshold for 5°F off was 148.8 BTU/ft^2-hr. The energy flow was calculated between the time when the collector pump started and the time when the start-up insolation threshold was reached. Similarly, the energy flow was calculated between the time when the 5°F off insolation threshold was reached and the time when the collector pump shut off. For the monitoring period of October 17 through October 22, the extra collected energy at start-up was 103,050 BTU and the extra collected energy at shutdown was 272,300 BTU. This amounts to a sum of 0.33 million BTU or 5% during start-up and shutdown.

The above method resulted in a 5% collection improvement compared to a 3.8% to 4.3% improvement with the first method. The energy collection improvement results from the longer collector pumping time. Although the improvement is small, it is quite cost effective because no new equipment is used.