ETEC-87-7

Solar in Federal Buildings Program

Quality Site Seasonal Report
Fort Devens Launderette, SFBP 1751
December 1984 Through June 1985

Prepared for the U.S. Department of Energy
Division of Solar Heat Technologies
under Contract Number DE-AC03-76SF00700

Energy Technology Engineering Center

Operated for the U.S. Department of Energy
by Rocketdyne Division, Rockwell International

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS price codes
Printed copy: A08
Microfiche copy: A01

ETEC-87-7

ETEC--87-7

DE88 003625

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Fort Devens Launderette, SFBP 1751
December 1984 Through June 1985

by
T. L. Logee

Vitro Corporation
14000 Georgia Avenue
Silver Spring, Maryland 20910

Prepared in Support of
The Solar in Federal Buildings Program
for the

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P.O. Box 1449, Canoga Park, California 91304

MASTER

Contract: DE-AC03-76SF00700
Issued: 15 October 1987

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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 Fort Devens Launderette (Project No. 1751) located at Fort Devens, Massachusetts. This 2562 ft^2 flat plate solar system is used to heat hot water for the washing machines in the Launderette. This report, in support of the system analysis and applications research area, presents the performance results of the Fort Devens Launderette 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 Fort Devens Launderette was designed and constructed as part of the Solar in Federal Buildings Program (SFBP). This retrofitted system was one of eight systems selected for quality monitoring. The purpose of this monitoring effort was to document the performance of quality state-of-the-art solar systems in large federal buildings.

The launderette is part of the Post Exchange complex at the Fort Devens Army Post in Fort Devens, Massachusetts. The solar system preheats hot water for the coin operated laundry which has an estimated 25,000 customers per year.

There are 108 collector panels comprising the 2,563-square foot collector array. Collected solar energy is stored in a 3,800-gallon tank. Propylene glycol is used to protect the solar array from freezing. Two immersed heat exchangers provide heat transfer from the propylene glycol to directly heat the DHW supply water in the storage tank. Auxiliary energy is supplied by gas and oil boilers.

This solar system can be considered one of a kind and as such is a prototype. The lessons learned from building and operating this system should be used to correct design deficiencies and improve the performance of future solar systems for this application.

Highlights of the system performance at the Fort Devens Launderette solar system during the December 1984 through June 1985 monitoring period are presented below:

- The solar system was reliable. There were no malfunctions which prevented collection and utilization of solar energy. The system was available more than 99% of the time.

- In comparison to a similar NSDN solar system monitored in the Solar Heating and Cooling Demonstration Program, the Fort Devens solar system performed much better, delivering 404 BTU/ft^2 day to the load versus 267 BTU/ft^2 day for Cathedral Square.

- Fossil fuel savings were 366 million BTU over the seven months of monitoring, at a cost in electrical operating energy of 8.46 million BTU (2,477 kWh). At costs of $6.28/million BTU for natural gas and $26.06/million BTU for electricity, this equates to a fossil fuel savings of $2,300 and an operating cost of $220. The F-Chart extrapolated annual savings would equal $3426 net. The annual operating cost would be $363.

- The annual F-Chart predicted savings was $1.59 per ft^2 while the annual F-Chart extrapolated savings was $1.34 per ft^2.

- A cost study conducted for the Fort Devens site indicated that the cost to build a similar commercial installation would be $85,106 in 1985

dollars. Based on this, the cost per ft^2 of gross collector array for this type of installation would be $33.30. Dividing the normalized installation cost by the extrapolated annual solar energy delivered yields a cost of $235/million BTU.

- The DHW load (603 million BTU's over the seven month monitoring period) was 58% of the design estimate.

- The total solar energy delivered to the load over the seven month monitoring period was 220 million BTU's. This was 112% of that predicted by F-Chart. The percentage of incident solar energy delivered to the loads was 32%.

- The fraction of the load actually supplied by the solar energy system over the monitoring period was 36% as compared to the F-Chart prediction of 39% for the same period. The F-chart predicted annual solar fraction was 41% based on design parameters and the F-chart extrapolated annual solar fraction was 35% based on measured values.

- The solar system efficiency, defined as the solar energy delivered to storage minus the solar parasitics divided by the total insolation, was 32%. The solar conversion efficiency, defined as the solar energy delivered to the load minus the solar parasitics divided by the total insolation, was 31%. The solar energy delivered to the load divided by the solar parasitics (COP) was 26, where the parasitics over the monitoring period were 2,480 kWh.

- The actual solar insolation in the plane of the collector over the monitoring period (677 million BTU) corresponded closely with the long-term insolation (687 million BTU).

- Collector subsystem performance was less than expected for the flat plate collector array. Collector array efficiency was 33% and the collector array output divided by insolation available during solar system operation (i.e., the operating collector array efficiency) was 42%.

- Collector-storage transport losses were low - only 0.5% of the collected solar energy.

- Storage losses were average compared to NSDN sites, but high compared to theoretical calculations. The losses from the 3,800-gallon storage tank amounted to 3.93 million BTU's for the seven month monitoring period. The effective R-value for the storage tank was 7.7 versus 30 as specified in the construction specification. The average storage tank temperature was 76°F.

- The collector control system worked well, with very little energy rejection and a ratio of operational incident energy to total incident energy of 0.80.

- The collector loop heat exchanger effectiveness averaged over the monitoring period was 32%. This was good performance for an immersion heat exchanger.

- The measured collector flowrate was 90.6 gpm compared to the design collector flowrate of 77 gpm.

Lessons learned from the Fort Devens site are:

- The "good engineering practice" which should be praised is the use of a simple solar energy collection and delivery to load system with almost immediate use of the solar heated water. This collector array requires only a temperature differential controller and no system interface controller. The result of this design is high solar energy utilization.

- The propylene glycol antifreeze solution is a required component of this system. Since propylene glycol has a lower heat capacity, there is a small reduction in collector efficiency. The reduction in efficiency at Fort Devens was estimated to be only 2-1/2% below a comparable system using water at the design flow rate. This reduction was minimized by the 75% increase in flow rate over the 0.022 gpm/ft^2 rule of thumb. The poorer propylene glycol heat transfer properties should be compensated for by a larger flowrate.

- There is also another effect on collector efficiency when using a more viscous fluid than water. This is the effect of flow rate and fluid characteristics on the heat transfer coefficient between the riser tube and the fluid. At Fort Devens, the propylene glycol was usually at a flow rate and temperature which would result in laminar flow and therefore a lower heat transfer coefficient. The effect on collector efficiency was small.

- There was some flow imbalance within collector subarrays at Fort Devens. Fortunately, good design practice reduced the flow imbalance effects to 4% of the measured collector $F_R(\tau\alpha)$. The installer used variable sized orifices in the inlet and outlet header connections to reduce the flow imbalance between panels.

- The storage tank loss coefficient was similar to the theoretical calculated heat loss rate. This good storage performance is attributed to the high utilization of solar energy which reduced storage temperatures quickly and the entry of cold supply water at the bottom of storage which served to limit saddle losses. Thermosiphoning to the collector did occur and accounts for the higher quiescent tank loss rate.

- Perhaps the least effective component in the solar system was the immersed heat exchanger. The immersed heat exchanger effectiveness was lower than expected and may have caused higher collector plate temperatures. This problem was mitigated somewhat by the load timing and cold supply water entering the tank near the heat exchanger.

- To maximize the collector area that could be placed on the roof, the designer spaced the rows of collectors so that there was about 10% self-shading in December. The net result was an increase in total solar energy collected over the year when compared to a roof of comparable area and no collector self-shading.

- The solar storage tank is oversized. F-Chart showed that a 1500 gallon tank will yield more solar energy to the load than the present 3800 gallon tank. A study performed by ETEC using the WATSUN simulation program confirmed that the smaller tank was more cost effective.

- The collector support structure which overhangs the roof is not necessarily cost effective. A collector array mounted on the existing roof would be more cost effective.

- The F-Chart model appears to underpredict solar energy utilization for this solar system. A good agreement on storage losses was obtained with a storage UA only 36% of theoretical.

QUALITY SITE SEASONAL REPORT

FORT DEVENS LAUNDERETTE, SFBP 1751
DECEMBER 1984 THROUGH JUNE 1985

by T. L. Logee

Section I

OVERVIEW

A. INTRODUCTION

The solar in Federal Buildings Program (SFBP) is a multiyear 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 was begun 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 performance for the Fort Devens Launderette solar system during seven months monitoring by Vitro Corporation.

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 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 in 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 monitoring program for the Solar in Federal Buildings Program (SFBP) sites began in the spring of 1984 when ETEC sent documentation on the eight 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 Fort Devens Launderette solar system was shipped in September 1984, and installed by a local contractor in early October 1984.

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 the Fort Devens sensors was first transmitted back to Vitro Corporation for analysis in October 1984. Data from three other sites was also being received at this time. 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. The data was processed on an IBM 3033 computer at Vitro Corporation. This processing included error checking, performance evaluation and data base maintenance. The Fort Devens solar system was monitored through June 1985.

Section II

SYSTEM DESCRIPTION

A. SITE AND CLIMATOLOGICAL DATA

The Fort Devens Launderette is located on the Fort Devens Army Base at Fort Devens, Massachusetts. The latitude is 42.1°N, the longitude is 71.6°, and the elevation is 340 feet. Climatological (insolation and temperature) data for Boston, Massachusetts, 38 miles east of Fort Devens, are used in this report.

Temperatures at Boston average 51.3°F for the year, ranging from a low of 29.2°F in January to a high of 73.3°F in July. There is an average of 5,621 heating degree days in Boston. Since Fort Devens is about 38 miles inland, temperatures there are somewhat cooler and consequently there are also more heating degree days. Expected sunshine ranges from a low of 742 $BTU/ft^2/day$ in December to a high 1,738 $BTU/ft^2/day$ in June at the collector tilt of 35 degrees.

B. SOLAR SYSTEM

The solar system is a flat-plate closed loop system which preheats city water for the laundry. Selective surfaced Sunworks Solector collectors supplied with a propylene glycol solution provide solar heat to the 3,800-gallon solar storage tank. On demand cold city water under city pressure circulates through the storage tank picking up heat from an immersed tube bundle heat exchanger. The water is then heated to a delivery temperature of 142°F by the auxiliary gas and oil boilers before supplying the 50 washing machines in the launderette. About 25,000 customers a year use the facility. The solar energy and auxiliary interface is shown schematically in Figure 1.

1. Collector Loop. The collector subsystem is comprised of 108 Sunworks Model LB50211BC selective surfaced, single-glazed collectors. These are arranged in six rows of 18 panels each for a gross array area of 2,562 square feet, (2338 ft^2 net area) Figure 2. The array faces 19.5°E of south at a 35° tilt. The spacing between the rows is 7.5 feet. The collectors have internal manifolds. A 56% propylene glycol solution by weight is used for freeze protection. The ASHRAE test results (Reference 1) provided by Sunworks list the $F_R(\tau\alpha)$ as 0.719 and the loss rate $F_R(U_L)$ as 0.709 (See Reference 2).

The propylene glycol fluid is pumped into the West end of each row and exits the East end of the row. Flow balancing for each panel is provided by a series of couplings with different sized orifices joining the eighteen collectors that make up a row. The first nine collectors have the orifice coupling in the lower (inlet) manifold, the last nine in the upper (return) manifold. This arrangement of orifices within the manifold couplings permitted easier connection and piping of collectors.

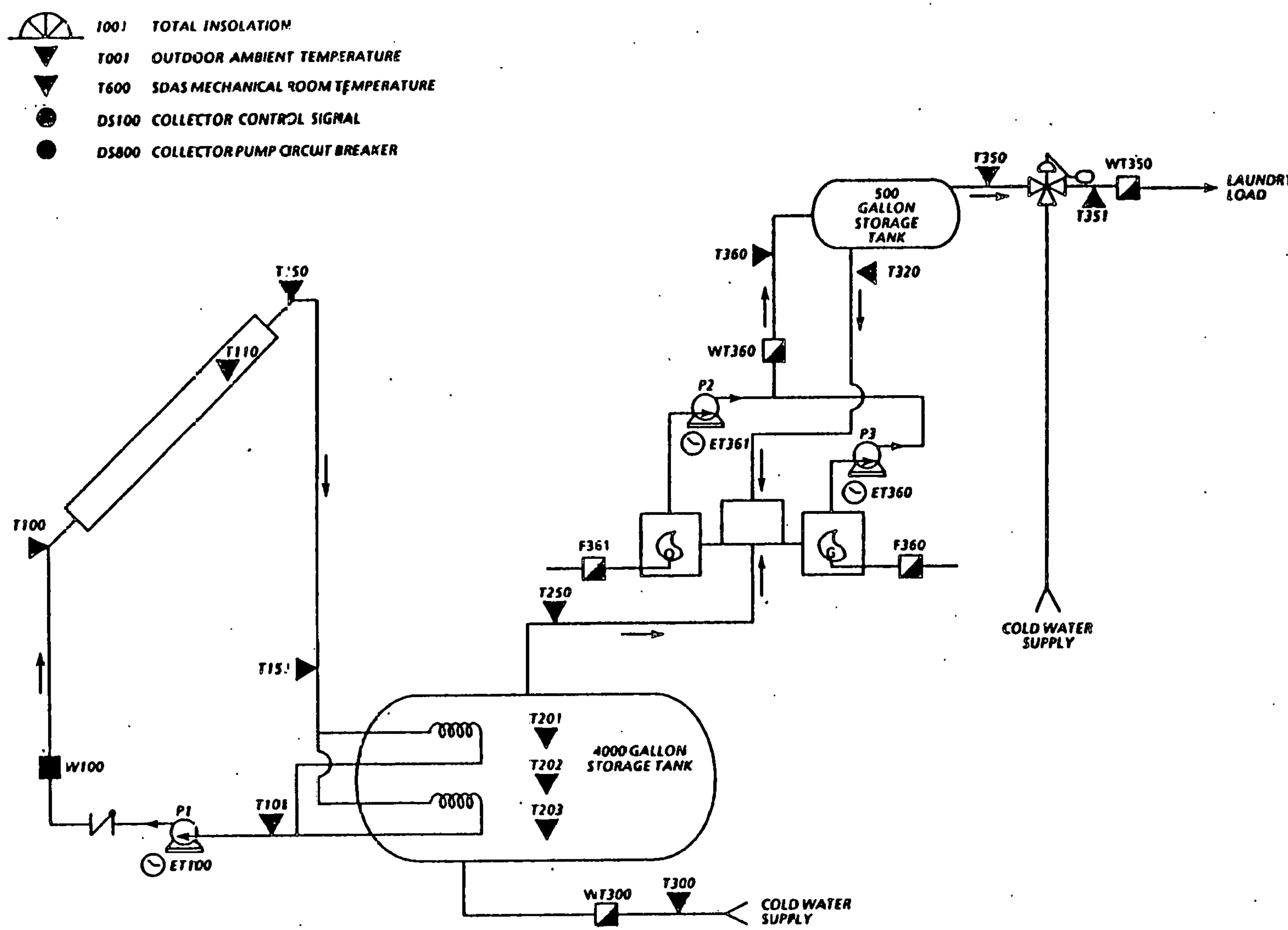


Figure 1. Sclar Energy System Schematic
Ft. Devens Launderette

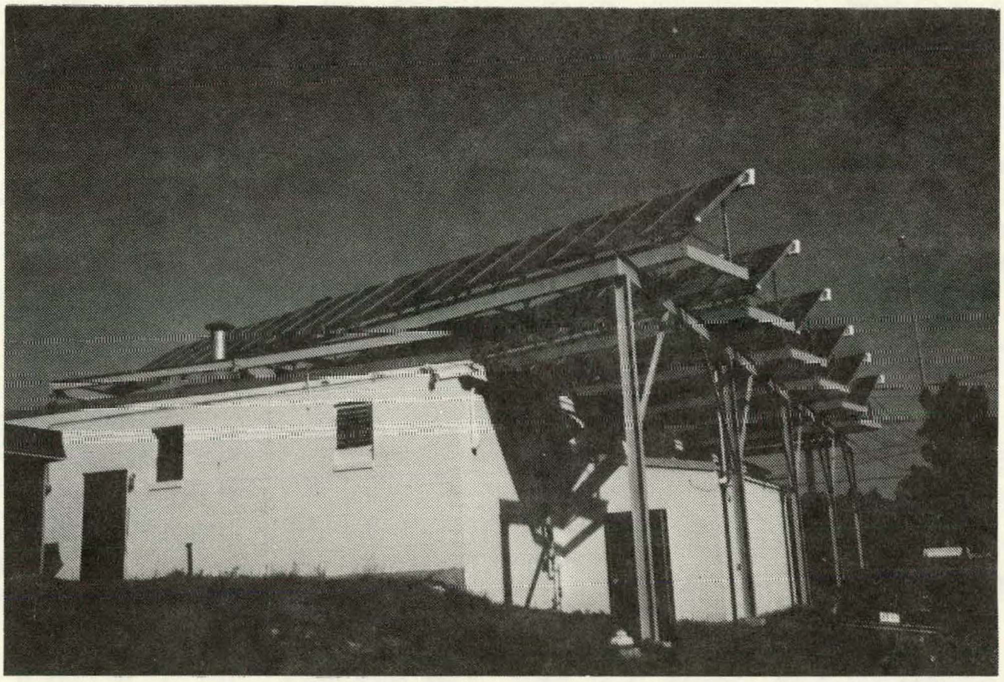


Figure 2. Collector Array, Showing Steel Support Structure
Fort Devens Launderette

The design collector flow rate was 77 gpm but actually measured 90 gpm. This is about twice as high a flow rate as the .02 gpm per square foot rule of thumb. The pump is a 3 hp Aurora, Type 344 sized for 50 feet of head, Figure 3.

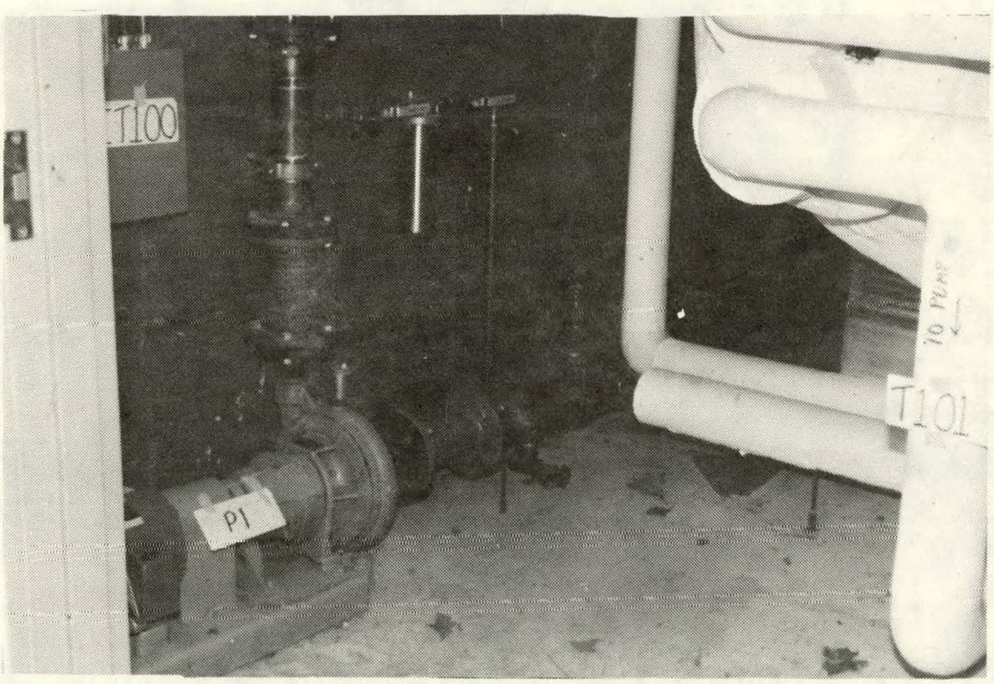


Figure 3. Collector Pump
Fort Devens Launderette

The collectors are supported by a large steel structure which is raised above the roof of the building. There were also more collectors than the building roof could accommodate, so the steel structure was extended beyond the building on the northeast side, Figure 2. As a further effort to maximize the collector area that could be placed on the roof, the designer angled the collector rows at a -20° azimuth, then placed them with a spacing (14 ft) and tilt (35°) that resulted in some shading in the winter months - about 10% in December, 7% in January and .9% in February. The net result was a predicted increase in solar harvest over the year, above that which could be realized with a tilt and spacing that avoided any shading.

2. Control System. The primary collector on/off control is provided by an Independent Energy C100 differential temperature controller, Figure 4. This unit is set to turn on the collector pump when the temperature of the collector panel control sensor is 20°F above the temperature of the storage sensor. The collector sensor is located on the last panel in the second row and is glued to the back of the collector plate. The storage sensor is located in the bottom third of the tank and near the immersed coil heat exchanger. The turnoff set point is 5°F. There is a high limit switch on the storage tank which is set at 180°F. Above 180°F, the collector pump stops and the collector fluid will boil out through the pressure relief values. There are no controls on the load side of the solar energy system. Makeup water always flows through the solar storage tank regardless of the storage to makeup water temperature difference.

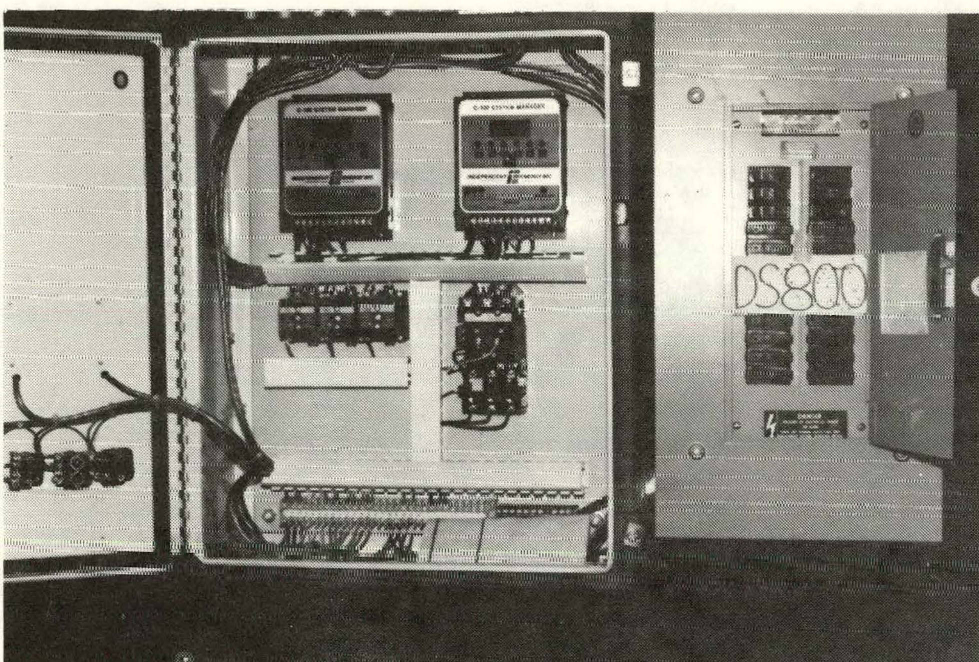


Figure 4. Solar Control Module
Fort Devens Launderette

3. Storage. The pressurized storage tank has a volume of 3,800 gallons. The pressure relief valve is set for 110 psig. at 210°F. The tank is six feet in diameter and 18 feet long insulated with 4 inches of sprayed on isocyanurate foam with an R-value of 30. The tank is mounted

horizontally on two large steel saddles. The faces of the saddles are insulated with 1" aluminum faced foam board. Immersion heat exchangers provide isolation of the propylene glycol collector fluid from the city water used in the laundry. There are two of these immersed heat exchanger tube bundles, each containing 315ft^2 of surface area located at the south end of the tank in the bottom quarter (Figure 5).

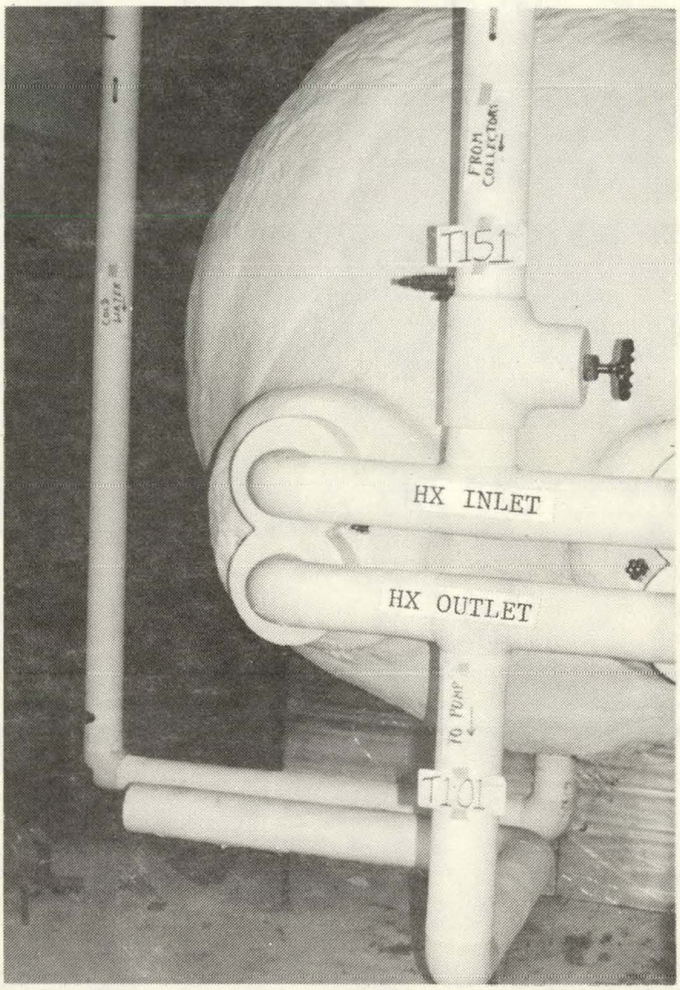


Figure 5. Solar Storage Tank Showing Immersed Heat Exchangers, Fort Devens Launderette

4. Transport. All of the collector array piping is copper pipe. It is piped in a reverse return configuration. There are 42' of 2" supply and 19' of 2" return pipes connecting the array to storage. The connecting pipes to the six rows are 25' of 1-1/4" pipes. As the supply and return pipes extend the length of the array, they are stepped down from 2" to 1-1/2" and 1-1/4" pipes. There are 33' of 2" pipe, 44' of 1-1/2" pipe and 28' of 1-1/4" pipe. All of the piping is insulated with 1" thick isocyanurate.

The propylene glycol solution is circulated through the collectors and heat exchangers in the storage tank by a 3 hp Aurora pump, Type 344 sized for 50 feet of head. Makeup water is provided manually since it must have antifreeze added.

C. CONVENTIONAL SYSTEM AND INTERFACE

There is a seven day a week hot water load placed on the solar system by the laundry. Cold city water is preheated as it passes through the solar storage tank. The preheated water then passes into a 500-gallon auxiliary storage tank where it is heated to about 160°F. The auxiliary storage is heated by recirculation from the boilers. During most of the monitoring period, the auxiliary boiler control was set to 190°F. This caused the storage temperature to remain at about 160°F while the delivery temperature was about 140°F. In the last two months, the gas boiler set point was reduced to 160°F and consequently the auxiliary storage was maintained at 142°F, while the delivery temperature was reduced to 138°F.

Because the gas boiler was not able to maintain the delivery water temperature during high demand periods, an oil boiler was installed at the Fort Devens Launderette. The oil boiler is set to start-up if the gas boiler is on and the control sensor is 10°F below the set point.

Section III

MONITORING APPROACH

This SFBP solar systems 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 schematic and instrumentation (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 throughout 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 Fort Devens Launderette, 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 where thermal losses occur 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 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 are 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, the 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 type flow meter (meter reading greater than 50% full range)	± 1.4% of full scale
Fluid Volume Displacement type flow meters	± 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
Fuel oil usage	± 4% of full scale

All sensors were within the limits of uncertainty shown above except the temperature sensors in the collector loop - T100, T150 and T151 which had uncertainties of ±1.3°F, ±1.2°F and ±1.0°F respectively. Flow sensor W100 read 6% above the full scale calibration but not beyond the resolution or accuracy of the sensor.

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, when measuring the amount of solar energy collected, the uncertainty is ±17% since this collector operates at a small (8°F) temperature difference and the temperature sensor uncertainties are greater than 1°F.

Section IV

EXPECTED MONITORING PERFORMANCE

A. ACCEPTANCE TEST

The acceptance test was conducted on July 18 and 19, 1983. Data was gathered at 15-minute intervals from 11:15 a.m. to 2:45 p.m. each day. The instantaneous insolation ranged from a low of 126 to a high of 317 BTU/hr-ft^2 and averaged 249 BTU/hr-ft^2. Ambient temperatures ranged from 83.5°F to 95.9°F.

The collector test results were based on a BTU meter measured flow rate of 75.7 gpm. This flow rate was 16% below the flow rate of 90 gpm measured during long-term testing. It is not known whether the system flowrate was changed between the acceptance test or whether the acceptance test measurement was in error.

On July 18, 1983, there were 2.20 million BTU of insolation and 0.99 million BTU collected. This resulted in an average collector efficiency of 45%. On July 19, 1983 there were 2.61 million BTU of solar energy incident on the collectors and 1.18 million BTU collected. This amounted to an average collector efficiency of 45%. Vitro measured the operational efficiency for June 1985 at 43%.

The acceptance test plot of instantaneous collector efficiencies versus operating point is presented in Figure 6. The measured points fall above the 50% ASHRAE 93-77 test line, fulfilling the acceptance test criteria established in ETEC Document SFBP-XT-0015 (Reference 9). The points on the collector efficiency plot measured by Vitro for June 1985 are several percent above the 75% ASHRAE 93-77 test line. The acceptance test results are quite consistent with the results of Vitro measurements.

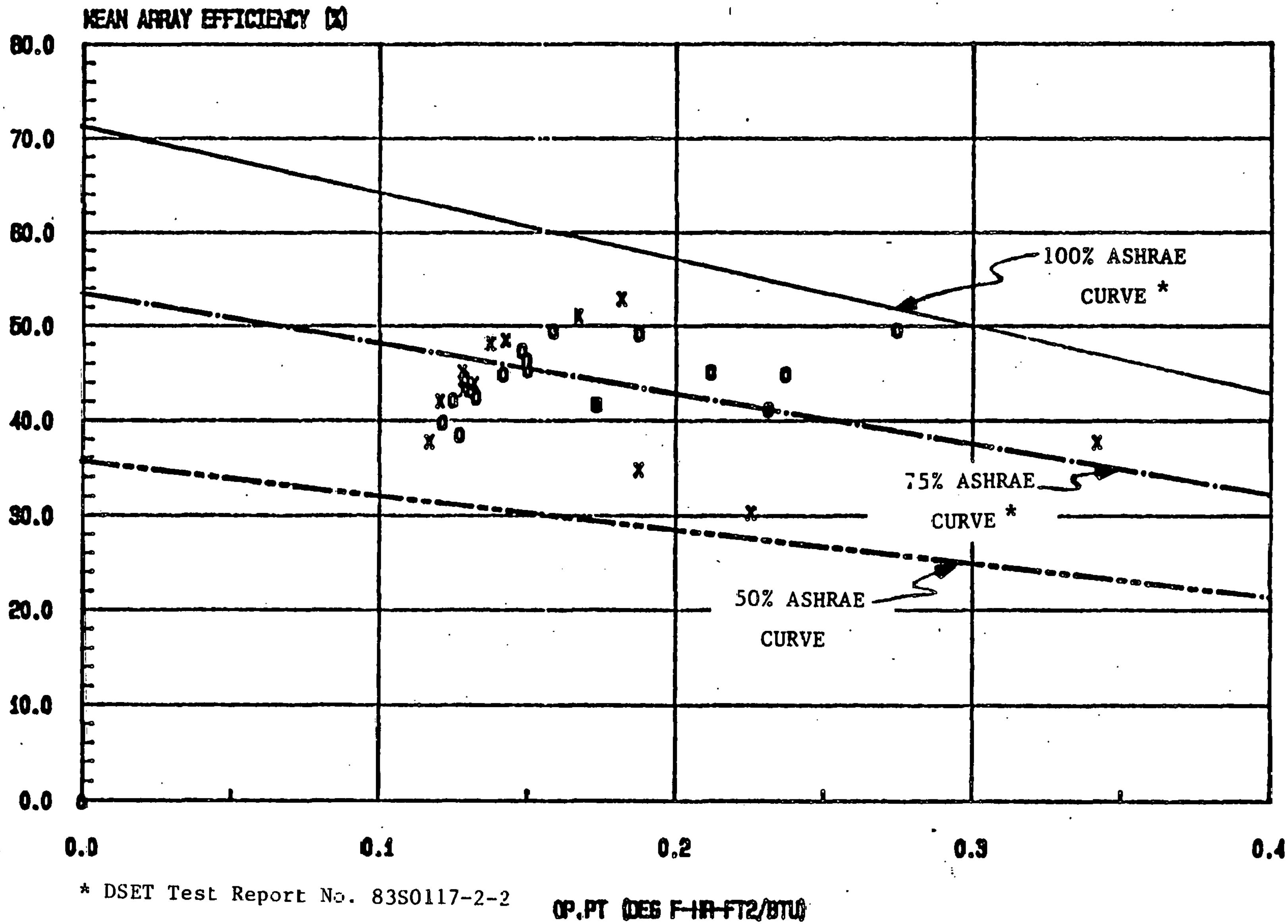
B. THERMAL PERFORMANCE

An F-Chart analysis was run for the Fort Devens collector system. This analysis used measured loads and weather data for the seven months monitored and average loads and long-term weather for months not monitored. The ASHRAE 93-77 test collector efficiency curve was input to F-Chart. (See Appendix F, Table F-2 for the input parameters used.)

The F-Chart analysis predicted an annual solar fraction of 41% (See Table 1). The predicted solar fraction was for loads of 1038 million BTU being met by 424 million BTU of solar energy. This is a predicted average of 35.3 million BTU per month of solar energy delivered.

C. PREDICTED ENERGY SAVINGS

The annual fossil fuel savings predicted by F-Chart are 706 million BTU or 58.8 million BTU per month using an assumed 60% conversion efficiency



* DSET Test Report No. 83S0117-2-2

Figure 6. Acceptance Test Plot of Overall System Efficiency, Fort Devens Launderette

for the boiler. (The assumed boiler efficiency is standard in NBSIR 76-1137, Reference 3.)

Table 1. F-Chart Predicted Performance
Fort Devens Launderette

*** GENERAL SOLAR HEATING SYSTEM ***
** FLAT PLATE COLLECTOR **

	SOLAR MMBTU	LOAD MMBTU	QTANK MMBTU	AUX MMBTU	F
JAN	60.1	80.6	0.43	62.7	0.22
FEB	83.8	80.6	0.50	54.2	0.33
MAR	124.0	92.7	0.70	51.7	0.44
APR	119.0	87.0	0.63	47.0	0.46
MAY	126.0	80.6	0.57	36.1	0.55
JUN	111.0	92.7	0.36	48.0	0.48
JUL	131.6	89.0	0.56	39.6	0.56
AUG	119.5	89.0	0.53	42.9	0.52
SEP	109.1	86.1	0.52	43.8	0.49
OCT	92.3	89.0	0.47	53.9	0.39
NOV	54.7	86.1	0.30	66.6	0.23
DEC	53.0	84.9	0.33	68.2	0.20
YR	1184.1	1038.3	5.89	614.7	0.41

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

LOAD is the monthly hot water load on the system (MMBTU).

QTANK is the monthly total energy loss from the storage tank (MMBTU).

AUX is the monthly total auxiliary energy which must be supplied to the hot water load (MMBTU).

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

Section V

MONITORING RESULTS

A. THERMAL PERFORMANCE

1. Weather Performance. The measured and long-term weather for the seven months monitored are shown below in Table 2. The measured solar energy incident on the collector array is within two percent of the long-term average. The greatest deviation of the measured and long-term insolation occurred in March and June, each month having a 17% difference. (Note: the long-term weather for Fort Devens was referenced to the record from Boston, MA.)

The ambient temperatures for the monitoring period averaged two degrees warmer than long-term (49°F vs 47°F). Note that there are temperature data for only five months. The December and January measured temperatures were incorrect because of a nearby clothes dryer vent. The ambient temperature

Table 2. WEATHER CONDITIONS

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 1985

MONTH	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/ft^2-day) MEASURED (SE)	LONG-TERM AVERAGE	AMBIENT TEMPERATURE (°F) MEASURED (TA)	LONG-TERM AVERAGE	HEATING DEGREE-DAYS MEASURED (HDD)	LONG-TERM AVERAGE	COOLING DEGREE-DAYS MEASURED (CDD)	LONG-TERM AVERAGE
DEC	667E	742	*	33	*	1,023	*	0
JAN	756	848	*	28	*	1,145	*	0
FEB	1,168	1,096	31	30	960	999	0	0
MAR	1,559E	1,331	40E	37	765E	860	0E	0
APR	1,550E	1,480	50E	47	462E	507	3E	0
MAY	1,589	1,626	61	57	202	225	42	19
JUN	1,441	1,738	65	66	68	28	78	113
TOTAL	8,730	8,861	-	-	2,457E	4,787	123E	132
AVERAGE	1,247	1,266	49E	43	491	684	18E	19

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 values based on less than 90% but more than 40% measured data. See Appendix B for bridging methodolgy used.

* Indicates less than 40% measured data available.

The long-term average insolation values are calculated using the RBAR routine (Reference 10) from F-Chart to convert horizontal data to collector plane data, from derived long-term values for Boston, Massachusetts, Found in Input Data for Solar Systems (Reference 11). Long-term ambient temperature and degree-day data were taken from the same source.

sensor was moved at the end of January. After January, the largest deviation between the measured monthly average temperature and long-term temperature was four degrees Fahrenheit. Likewise, measured heating degree-days data exists for only five months. During the five monitored months, there were six percent fewer heating degree days than the long term average of 2619. Cooling degree-days were 7% less than the long-term data.

2. Collector. The performance of the Sunworks Solector collectors is shown in Table 3. The collectors operated at an average efficiency of 33% for the seven months of monitoring. During the monitoring period, collector efficiency improved each month (except January) because of the increased solar altitude each month which caused less shading. The designer told the author that in order to maximize the annual collected energy, the collector array rows were spaced so that there was some shading during winter months (See Section II, B.1).

Table 3. COLLECTION SUBSYSTEM PERFORMANCE

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 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)	COLLECTOR OPERATING ENERGY (CSOPE)	SOLAR ENERGY DIRECTLY TO LOADS (CSEO)	SOLAR ENERGY TO STORAGE (STEI)	DAYTIME AMBIENT TEMPERATURE (°F) (TDA)
DEC	53.0E	15.3E	28.9E	40.4E	37.9E	0.79E	N/A	15.2E	47E
JAN	60.1	14.3E	23.8E	39.8	35.9E	0.89	N/A	14.1E	33
FEB	83.8	25.8	30.8	64.6	40.0	1.00	N/A	25.7	36
MAR	124E	41.9E	33.8E	102E	41.0E	1.03E	N/A	41.8E	45E
APR	119E	41.6E	35.0E	98.1E	42.4E	1.46E	N/A	41.4E	57E
MAY	126	45.2	35.8	107	42.0	1.66	N/A	45.0	68
JUN	111	41.5	37.4	92.4	44.9	1.63	N/A	41.4	71
TOTAL	677E	226E	-	544E	-	8.46E	-	225E	-
AVERAGE	96.7E	32.3E	33E	77.7E	42E	1.21E	-	32.1E	51E

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

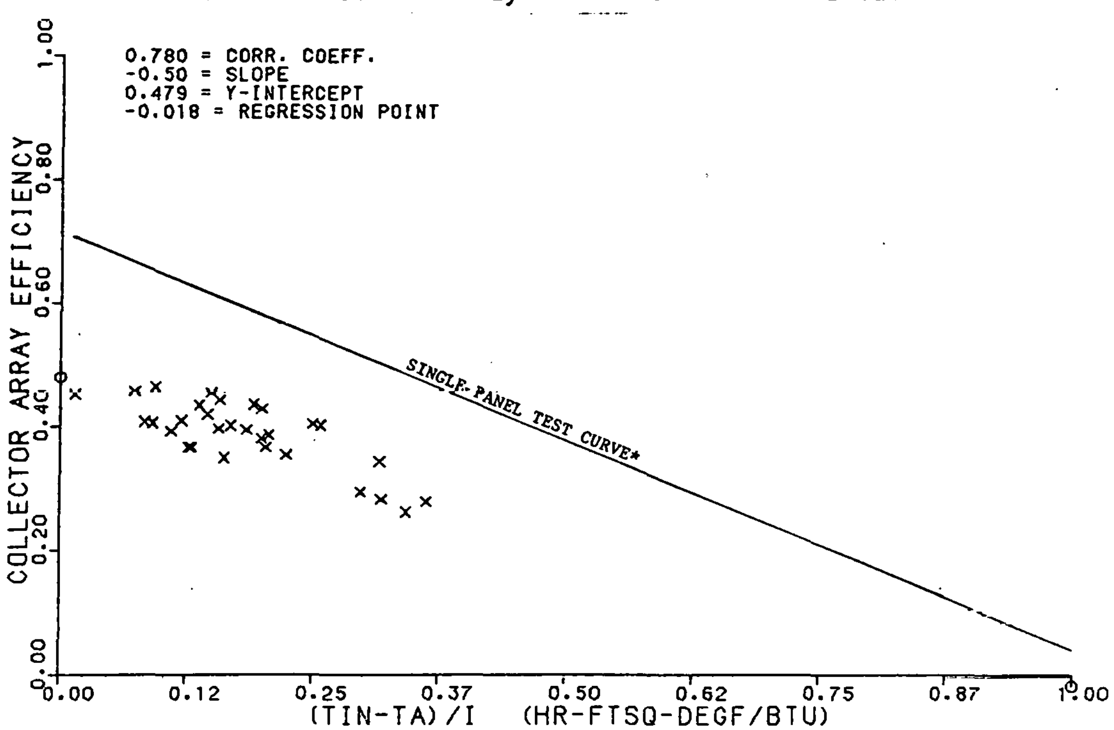
All values are rounded to the accuracy associated with the instrumentation used.

E denotes that the value is estimated from less than 90% but more than 40% measured data. See Appendix B for bridging methodology used.

There was a total of 226 million BTU of solar energy collected out of the 677 million BTU incident on the array. The collector efficiency measured during the time the collector pump was running, operational collector efficiency, was 42%. A total of 225 million BTU were delivered to storage. The one million BTU difference between the solar energy collected and that delivered to storage is due to pipe losses from the collector piping as determined from measured temperatures and the theoretical R value for the pipe insulation. As a result of good pipe insulation, less than 1/2% of the collected energy was lost. The collector pump required 8.46 million BTU or 2,480 kWh to operate. The collector subsystem was operational 100% of the monitoring period.

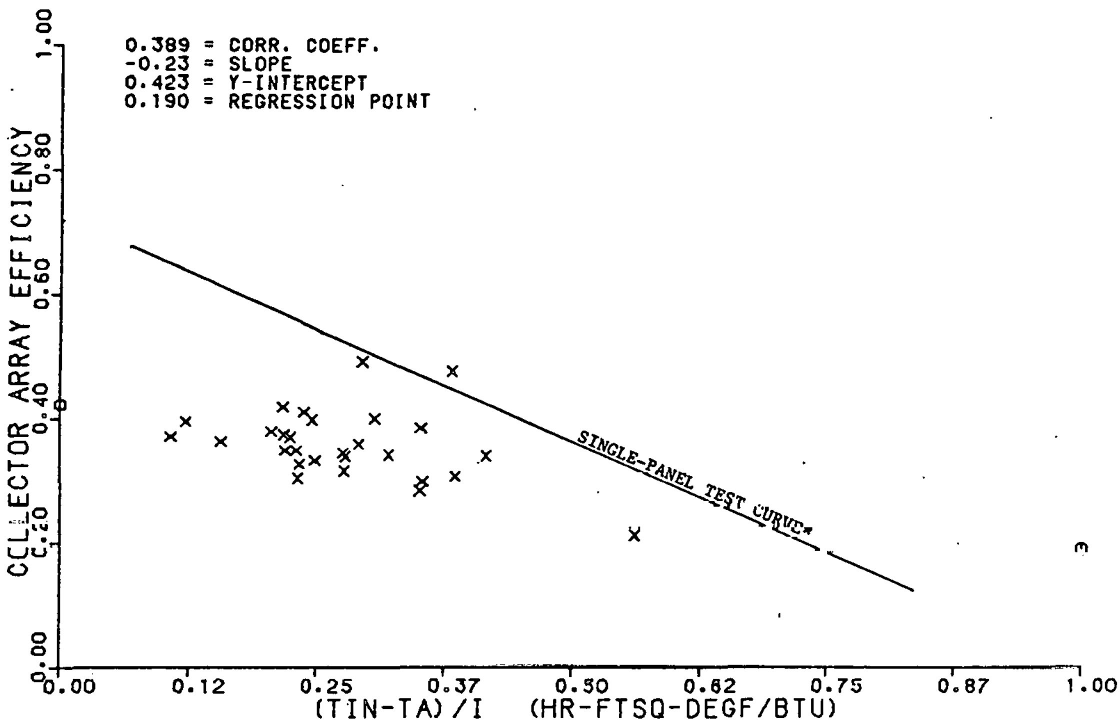
Freeze protection is provided by a 56% propylene glycol fluid. No overtemperature conditions occurred during the monitoring period.

Figures 7 through 13 show the measured curves of collector efficiency versus the collector operating point. Each plot is for hours during which there was continuous flow through the collector array. The first hour of continuous operation for each day is not considered. Transient effects related to startup of operation often result in higher and/or lower efficiencies than subsequent hours at the same operating point. Outlying points which are greater than three standard deviations from the first order curve fit of the data are also filtered. Note that the first order curve fit information in the upper left of the plot is only valid for the range of values of (TIN-TA)/I available. This plot is representative of the performance of the collector array for the month indicated. The ASHRAE



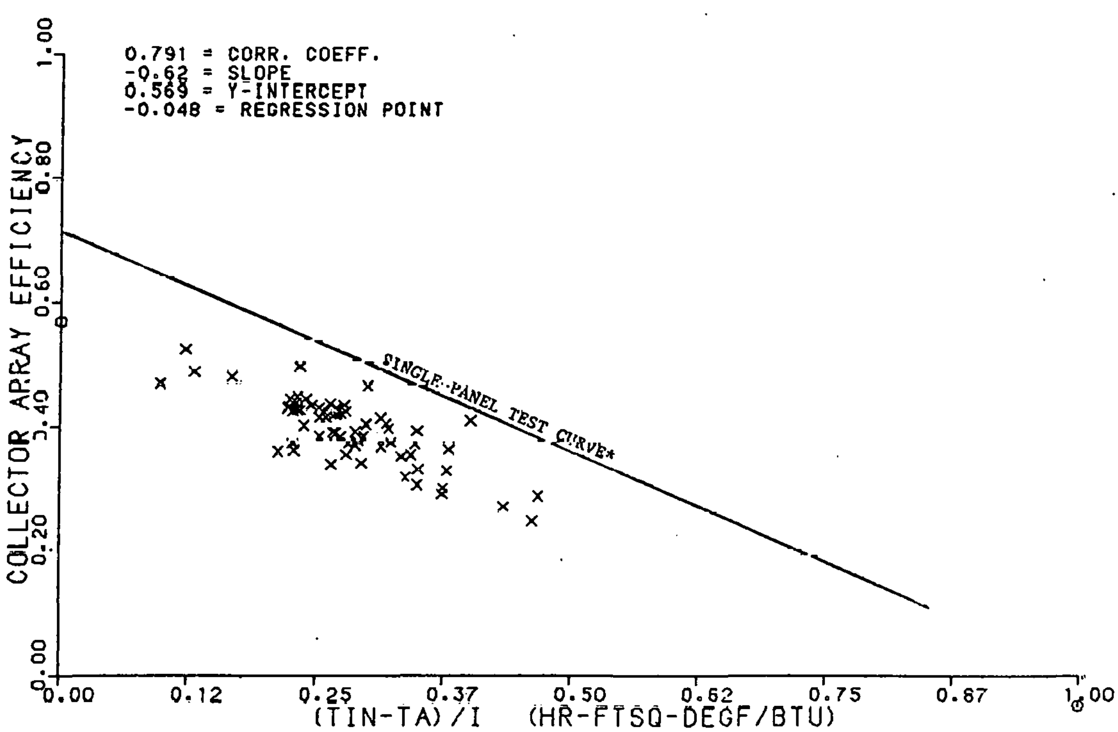
* DSET Test Report No. 83S0117-2-2

Figure 7. Collector Array Efficiency Plot
Fort Devens Launderette
December 1984



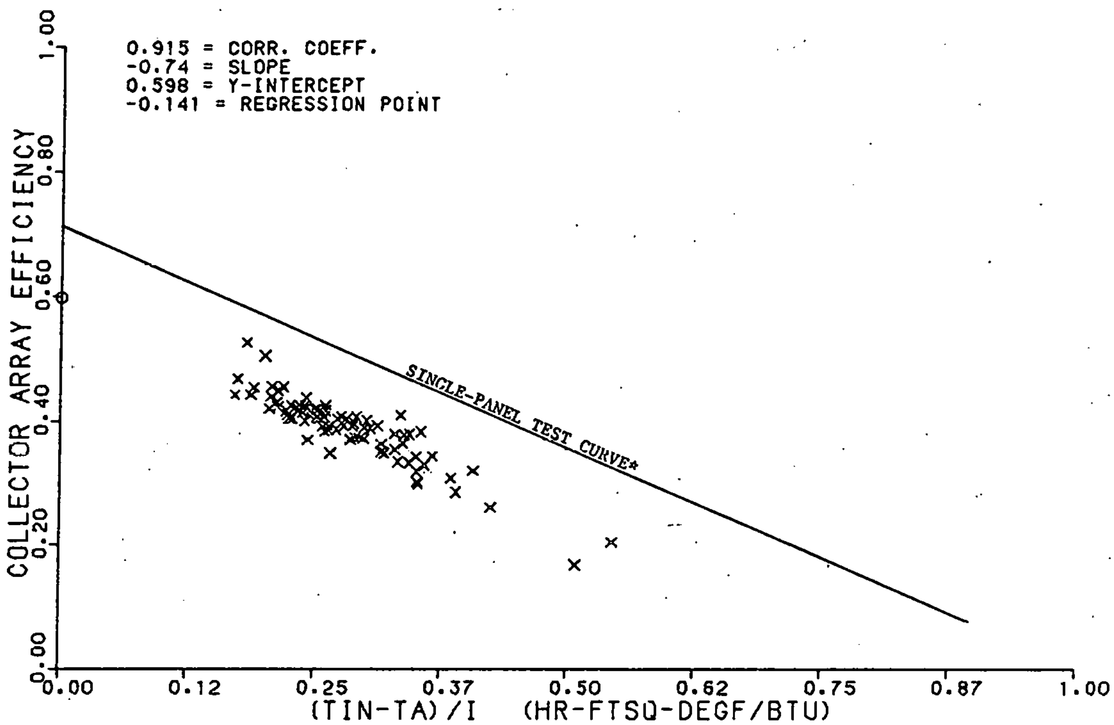
*DSET Test Report No. 83S0117-2-2

Figure 8. Collector Array Efficiency Plot
Fort Devens Launderette
January 1985



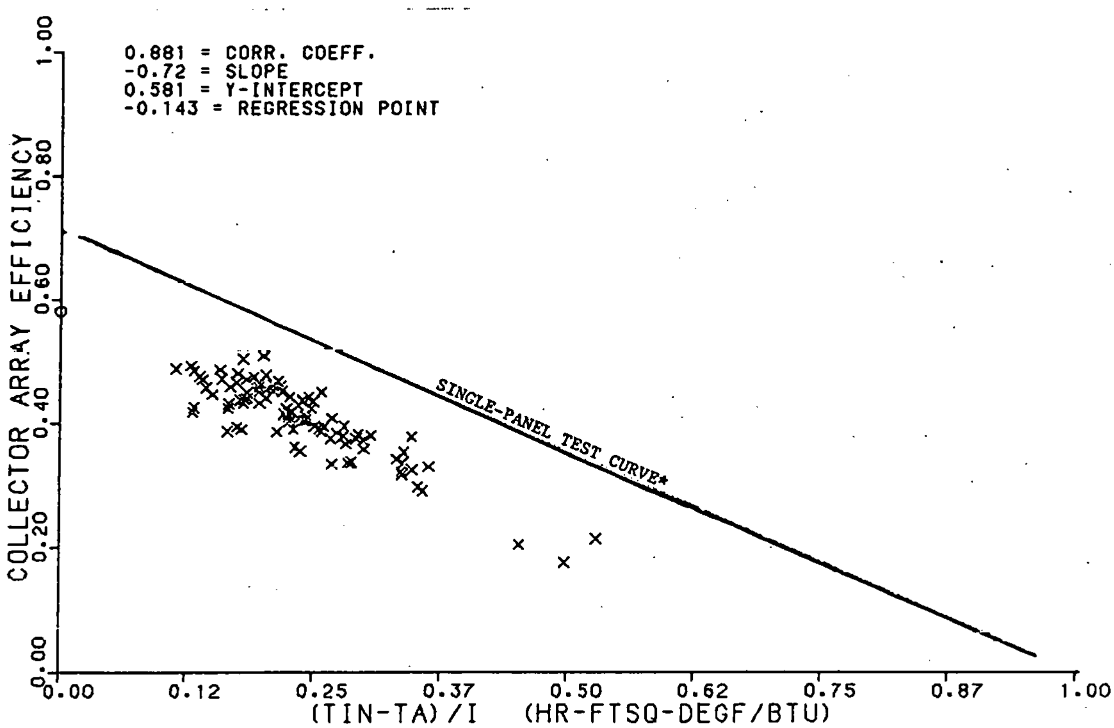
*DSET Test Report No. 83S0117-2-2

Figure 9. Collector Array Efficiency Plot
Fort Devens Launderette
February 1985



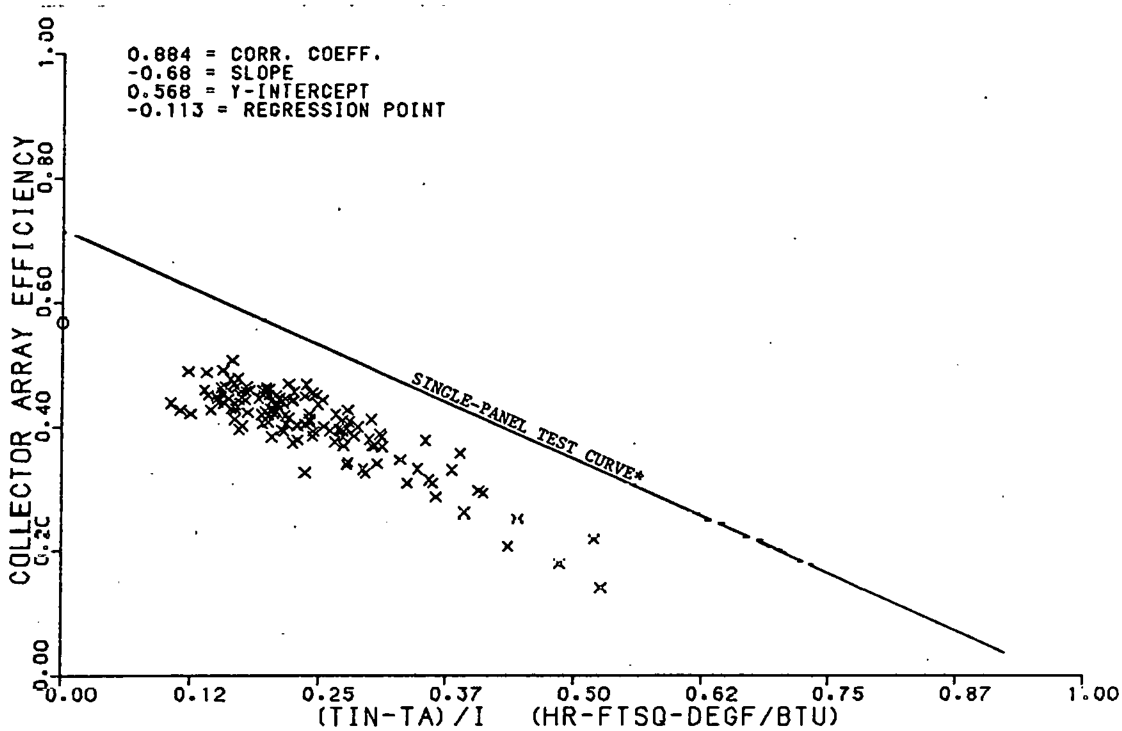
* DSET Test Report No. 83S0117-2-2

Figure 10. Collector Array Efficiency Plot
Fort Devens Launderette
March 1985



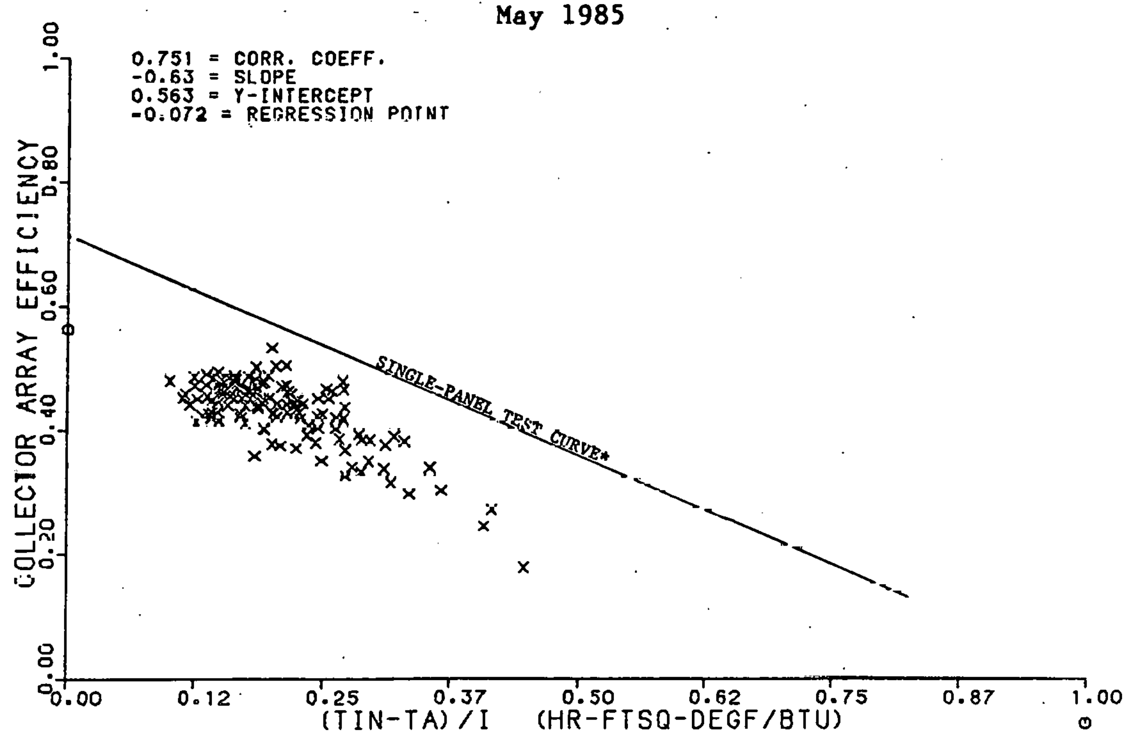
*DSET Test Report No. 83S0117-2-2

Figure 11. Collector Array Efficiency Plot
Fort Devens Launderette
April 1985



*DSET Test Report No. 83S0117-2-2

Figure 12. Collector Array Efficiency Plot
Fort Devens Launderette
May 1985



*DSET Test Report No. 83S0117-2-2

Figure 13. Collector Array Efficiency Plot
Fort Devens Launderette
June 1985

93-77 test curve is also shown. The test $F_R(\tau\alpha)$ is 0.714 and the test slope $F_R(U_L)$ is 0.709 (Reference 2). The measured curves fall reasonably close together and have an approximate "eyeball" average $F_R(\tau\alpha)$ of 0.59 and an $F_R(U_L)$ of 0.68.

The measured curve is 12% below the test curve. The reasons for this difference are discussed fully later in this section under Hardware and Instrumentation Problems. The major contributors to the difference between test and measured results are array piping losses, the heat transfer effects of propylene glycol, collector panel flow imbalance and measurement error.

3. Storage Performance. The solar storage tank at Fort Devens performed well. The monthly energy flows and storage temperatures are shown in Table 4.

Table 4. STORAGE PERFORMANCE

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 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-ft^2)	LOSS FROM STORAGE (STLOSS)
DEC	15.2E	14.3E	0.73E	99	63E	0.12E	0.17E
JAN	14.1E	14.8	-0.77	100	62	0.02E	0.07E
FEB	25.7	24.2	1.02	98	68	0.15E	0.48
MAR	41.8E	39.0E	-0.94E	91	79E	0.62E	3.74E
APR	41.4E	40.9E	1.20E	-	85E	-	-0.70E
MAY	45.0	45.9	-0.51	-	91	-	-0.39
JUN	41.4	40.5	0.34	99	84	0.16	0.56
TOTAL	225E	220E	1.07E	-	-	-	3.93E
AVERAGE	32.1E	31.4E	0.15E	98E	76E	0.13E	0.56E

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

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

E denotes an estimated value when less than 90% but more than 40% of data was measured. See Appendix B for the bridging methodology used.

There were 225 million BTU of solar energy to the storage tank and 220 million BTU of solar energy removed from storage during the monitoring period. With a change in internal energy of 1.07 million BTU and storage losses of 3.93 million BTU, storage efficiency was a very high 98%. The average storage water temperature was 76°F which helps account for the good storage performance. The effective heat loss coefficient was 0.13 BTU/hr-°F-ft^2, R 7.7. This is four times larger than the theoretical loss coefficient of 0.033 BTU/hr-°F-ft^2 (R 30) of the storage insulation. The storage losses, calculated from the theoretical loss rate and the temperature difference, were 1.05 million BTU. An independent estimate of the storage loss coefficient from a 40 hour quiescent period on December 31, 1984 and January 1, 1985 resulted in a loss coefficient of 0.24 BTU/hr-°F-ft^2, R 4.2.

The theoretical storage losses are equivalent to a heat loss coefficient of 0.138 BTU/hr°F ft^2. The UA values and percentage of the total UA are shown below:

Component	Heat Loss (BTU/hr°F)	Percentage (%)
Saddles	24.3	39
Tank	14.7	24
Uninsulated pipe & pump	19.5	32
Insulated pipe	3.4	5
	61.9 BTU/hr°F (R7.2)	100

Insulating the uninsulated piping, pump and saddles would reduce the UA to 34.7 (R 12.9) and most certainly be cost effective. Note that the present saddles are considered uninsulated although there is some insulation board loosely leaning against them. The saddles must be carefully insulated with firmly attached insulation for it to be effective.

A storage UA of 61.9 BTU/hr°F amounts to a loss of 4.6 million BTU during the monitoring period. This value is slightly greater than the losses measured during the monitoring period but does not include any energy losses due to thermosiphoning. The quiescent tank loss rate determined in December was 0.24 BTU/hr-°F-ft^2. The difference in these two heat loss rates is primarily due to thermosiphoning. During the December quiescent period, the collector plate sensor, T110, was nearly always 10°F above the ambient temperature. The difference between collector outlet temperature, T150 and collector inlet temperature, T100 was about 6°F. Apparently, the thermosiphoning flow was in the reverse direction through the collectors. A check of other months during the monitoring period also showed evidence of thermosiphoning except during very cold weather (ambient temperature below 32°F) when the storage tank was quite cool (about 60°F). The thermosiphon loss rate in December was 27,800 BTU/day. This thermosiphoning loss rate may be the maximum for this system.

It is somewhat surprising to observe thermosiphoning from the storage tank and through the immersion heat exchanger. This is even more surprising when one considers that the storage tank was well stratified with an 8°F to 12°F temperature difference between the bottom of storage and the middle of storage. Apparently, the heat exchanger was well into the area of warmer water. The piping layout however is conducive to thermosiphoning since the collector return drops 21 1/2 ft from the top of the 2nd collector row to the top of the heat exchanger. There are about 12' of horizontal pipe and eight 90° elbows between the top of storage and the top of the array. A spring loaded check valve in this pipe somewhere near the heat exchanger might prevent thermosiphoning.

Since the storage losses are derived from the difference between two large numbers, the uncertainty in the result can be quite large. Here the uncertainty is 360%. However, the uncertainty in the loss coefficient estimated from the 40 hour quiescent period is only 25% and the uncertainty in the theoretical loss rate is 18%. Additional discussion on the uncertainty of measurements is included in the Instrumentation and Hardware Problems section.

The storage tank is heated by two immersion type heat exchangers connected in parallel. The average heat exchanger effectiveness was 0.32. The manufacturer's heat exchanger effectiveness for this application is 0.50. The low heat exchanger effectiveness consequently caused higher collector inlet temperatures which resulted in less energy collected. This problem is discussed further in the Instrumentation and Hardware Problems section.

The system overtemperature set point of 180°F was never reached during the monitoring period.

A study of storage tank optimization done at Rockwell ETEC (Reference 12) shows that the storage tank at Ft. Devens could be much smaller and still deliver as much or more solar energy to the load. The impetus for reducing storage size is primarily to reduce system cost but also storage losses can be reduced. The study indicates a storage of 1280 gallons to 2500 gallons would be the optimum size range with perhaps a 1500 gallon tank being optimum. The optimum size is 0.5 to 1.0 gallons/ft^2 for the consistent daily load which occurs at Ft. Devens. The storage tank can be much smaller than the rule of thumb of 2 gallons per ft^2 because the load occurs at the same time as the insolation.

4. Domestic Hot Water Subsystem. The performance of the Domestic Hot Water (DHW) subsystem is shown in Table 5. Solar energy provided 220 million BTU or 36% of the load. The hot water load (total energy input to the DHW subsystem) was 603 million BTU and the hot water demand (DHW energy delivered, i.e. hot water load minus load side losses) was 551 million BTU. Auxiliary energy supplied 380 million BTU to the load. Total water consumption was 645,500 gallons. Figure 14 shows a plot of the mean hourly water consumption at Fort Devens during January. This plot is typical of the water usage for this system. There is a discrepancy between the measured hot water load and the hot water load calculated by adding solar energy used and auxiliary thermal used. The difference of 3 million BTU is due to measurement error.

The average cold water supply temperature was 49°F and the average hot water temperature was 154°F. Note that the average hot water temperature was reduced to 146° in May 1985. This occurred because the hot water supply temperature was reset to 140°F on May 15, 1985.

There was some difficulty encountered in measuring the hot water load and the auxiliary thermal energy used. These problems are explained in the Instrumentation and Hardware Problems section.

The tempering valve at Ft. Devens worked but not too well. That is, the valve performed some measure of tempering all the time but was not able to maintain the setpoint well.

During the first part of the monitoring period, the valve was reportedly set at 148°F. Around May 9, 1985 it was reset to 130°F.

Table 5. DOMESTIC HOT WATER SUBSYSTEM PERFORMANCE

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 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)
DEC	88.4E	16E	80.8E	17E	14.3E	77.9	117E	47E	158E	88,200E
JAN	80.7	18	73.1	19	14.8	65.6	98.5	44	158	77,600
FEB	80.6	30	73.7	33	24.2	53.3	80.0	45	158	77,800
MAR	92.6E	42E	85.0E	46E	39.0E	53.5E	80.3E	45E	162E	87,100E
APR	87.0E	47E	79.6E	52E	40.9E	38.1E	57.2E	49E	161E	85,000E
MAY	80.7	57	73.1	56	45.9	37.4	56.2	55	146	96,400
JUN	92.7	47	85.3	46	40.5	54.6	82.0	61	138	133,400
TOTAL	603E	-	551E	-	220E	380E	571E	-	-	645,500E
AVERAGE	86.1E	36E	78.7E	39E	31.4E	54.3E	81.6E	49E	154E	92,200E

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

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

E denotes an estimated value when there was less than 90% but more than 40% measured data.
See Appendix B for bridging methodology used.

Measured water temperatures indicated the earlier setpoint was closer to 142°F and the valve was very erratic.

When the temperature of the water leaving the auxiliary water tank was between 165°F and 170°F, there was about 10°F of tempering when there was a flowrate of 20 gpm. At low flowrates, there was no tempering. At lower auxiliary water tank temperatures there was less tempering, perhaps 6-8°F. At large flowrates, there was always some tempering even if the tempered water temperature was below the setpoint. (The temperature of the water from the auxiliary tank dropped quickly if one to two hundred gallons of cold water was introduced.)

After the tempering valve setpoint change to 130°F, the valve worked better, the closest approach to the setpoint was 133°F. The usual tempering amount was 1 to 3°F, since the hot water entering the valve was rarely more than 145°F.

The accuracy of tempering valve observations is decreased by the 5.33 minute scan interval and by the error on the inlet and outlet temperature sensors. The outlet temperatures did not appear to change if the flow rates were less than 10 gpm.

An estimate of the amount of tempering indicates that the tempering valve never provided more than 10% of the total outlet flow.

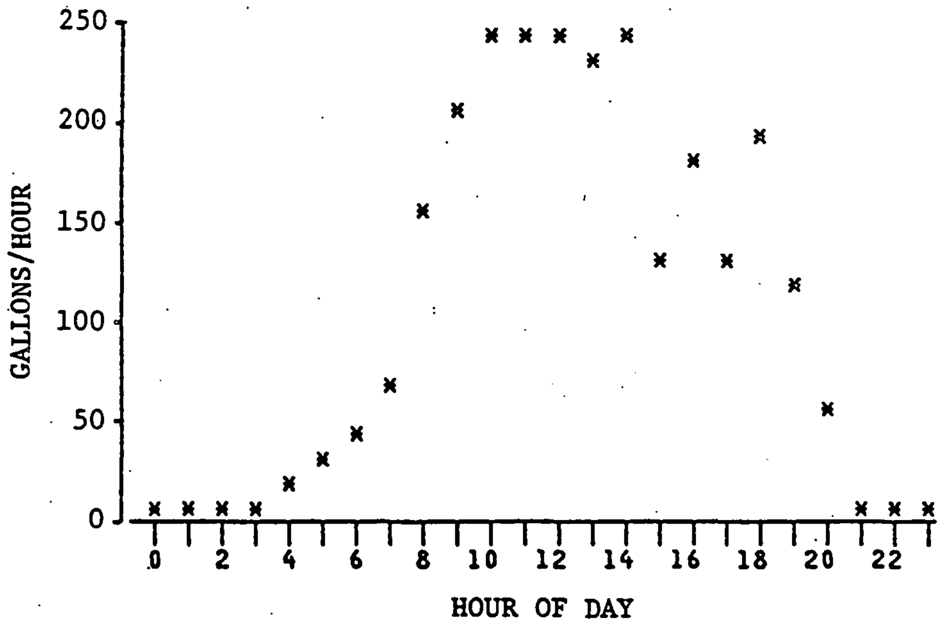


Figure 14. Hot Water Consumption Mean Hourly Plot
Fort Devens Launderette
January 1985

The boiler efficiency was estimated from the hot water demand minus the solar energy used plus the standby losses all divided by the fuel used. The estimated boiler efficiency was 67%.

Standby losses were estimated from three different periods of time when there was no hot water use. The average loss of 10,280 BTU/hr was then added to the hot water demand to find the hot water load.

It was not possible to measure the effect of the reduction in boiler setpoint from 190°F to 160°F and the change in tempering setpoint from 160°F to 130°F on standby losses. The boiler setpoint was changed on May 5th and the tempering valve was reset on May 9th. At the same time, the boiler recirculation pumps began to run continuously. With continuously running pumps the standby losses increased to between 30,000 to 40,000 BTU/hr. Both pumps run at the same time, thus keeping both boilers warm.

The boiler losses were estimated from other nighttime periods of 9 to 10 hours to be 5800 BTU/hr. The auxiliary tank loss rate was estimated at 4470 BTU/hr.

Figure 15 shows a bar graph of the monthly hot water load. This load is fairly constant from winter to summer because the hot water consumption increased from winter to summer as the ground water warmed up. Daily hot water loads during the month of April are shown in Figure 16. The daily loads are also fairly constant about the average of 2.9 million BTU per day. Note that there is a weekly cycle in the daily loads with a peak load of 4.2 million BTU occurring usually on Sunday. Saturday is often the second largest load of the week.

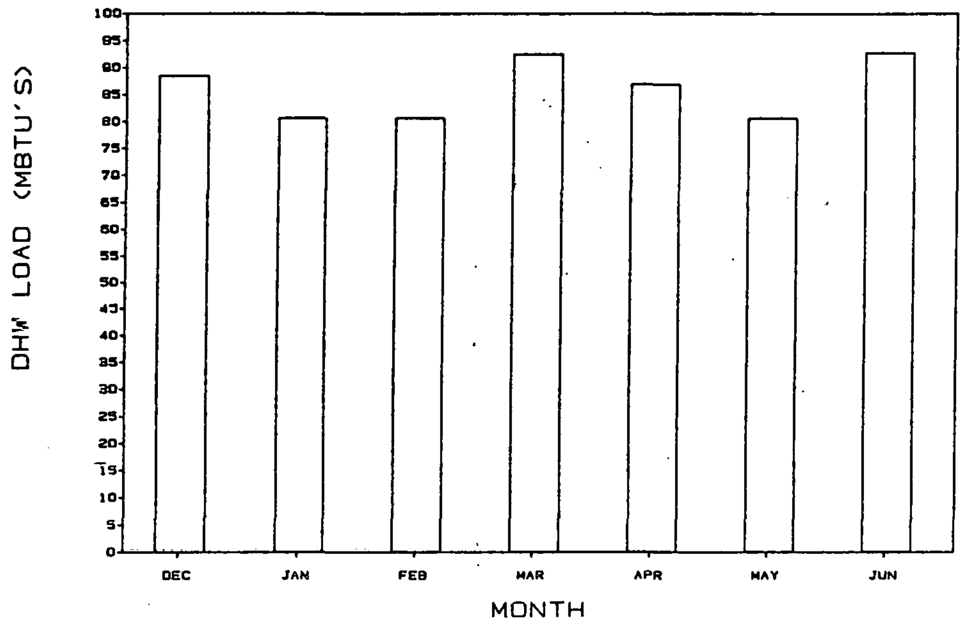


Figure 15. Monthly Hot Water Load
Fort Devens Launderette
December 1984 through June 1985

Typcial hourly loads are plotted in Figure 17. These represent the days of April 14th through the 20th. These hourly loads have a broader peak during the midday and an evening peak of lower intensity. The peak hourly load for the monitoring period occurred during this week.

Minimum, maximum and average hot water consumption for the month, day and hour are shown below. The average hourly hot water consumption is based on the hours the laundry was open.

	Monthly	Daily	Hrly	ASHRAE Hourly
Avg	92,200	3045	254	-
Min	77,600	0	0	-
Max	133,400	6753	935	1000

Measured peak usage is 94% of the ASHRAE Handbook value (Reference 13) for fifty washing machines.

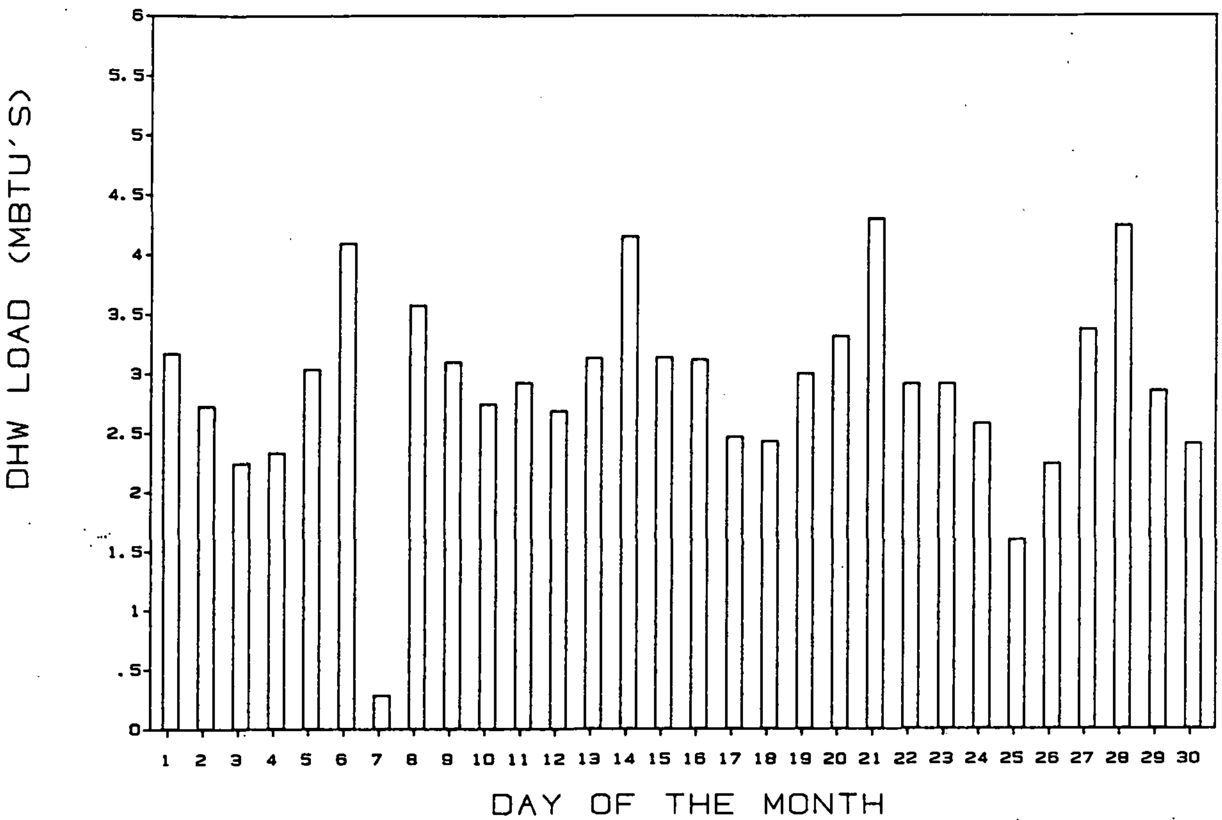


Figure 16. Daily Hot Water Load
Fort Devens Launderette
April 1985

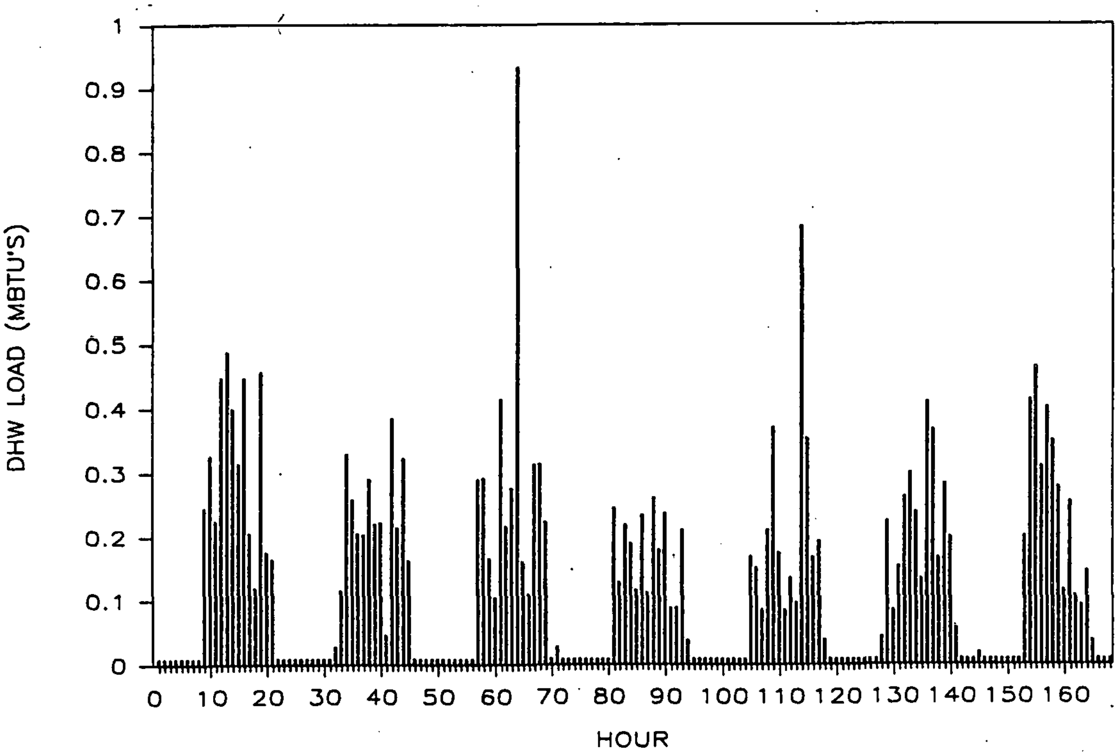


Figure 17. Hourly Hot Water Load
Fort Devens Launderette
April 14 through April 20, 1985

The implication is that, at least for the Ft. Devens case, the ASHRAE procedure for determining the maximum water consumption is adequate. Note that the average daily consumption is about 80% of the solar storage tank capacity. This is important information because for solar systems with consistent loads, like those at Ft. Devens, the storage tank should be sized so that all the collected energy is used in one day. On the average at Ft. Devens, the daily hot water consumption will not result in a complete turn over of water in the solar storage tank. Therefore solar storage losses will be higher.

5. Parasitic Power and Solar Coefficient of Performance. The solar system operating energy is shown in Table 6. There were 8.46 million BTU of operating energy used by the solar system. This energy was all used by the collector pump. No other pumps are necessary to move solar energy to the load, since city water pressure provides this motive power.

Table 6. SOLAR OPERATING ENERGY

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 1985

(All values in million BTU)

MONTH	COLLECTOR OPERATING ENERGY SOLAR-UNIQUE (CSOPE)	DHW OPERATING ENERGY SOLAR-UNIQUE (HWOPE1)	TOTAL SOLAR OPERATING ENERGY (SYSOPE1)
DEC	0.79E	N/A	0.79E
JAN	0.89	N/A	0.89
FEB	1.00	N/A	1.00
MAR	1.03E	N/A	1.03E
APR	1.46E	N/A	1.46E
MAY	1.66	N/A	1.66
JUN	1.63	N/A	1.63
TOTAL	8.46E	-	8.46E
AVERAGE	1.21E	-	1.21E

For a description of acronym in parentheses, refer to Appendix A

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

E denotes values that are estimated when there is less than 90% but more than 40% measured data. See Appendix B for the bridging methodology used.

The Solar System Coefficient of Performance (COP) is shown in Table 7. The collector subsystem had a COP of 27. The value of 27 is similar to COP's of 24 and 32 from two other SFBP hot water heating solar systems. The solar energy system COP of 26 was slightly less because of losses in the delivery system.

Table 7. SOLAR COEFFICIENT OF PERFORMANCE

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 1985

MONTH	SOLAR ENERGY SYSTEM	COLLECTION SUBSYSTEM
	(SEL) (SYSOPE1)	(SECA) (CSOPE)
DEC	18E	19E
JAN	17	16
FEB	24	26
MAR	38E	41E
APR	28E	27
MAY	28	27
JUN	25	25
AVERAGE	26E	27E

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

The COP of 27 for the collector is quite good when one considers that the flowrate is 25% higher than design. Additionally, there are flow balancing orifices in the manifold of each collector which increase the pressure head. The good COP's are a result of an efficient pump.

6. <u>System Performance</u>. Table 8 depicts the Solar System Thermal Performance for the seven month monitoring period. There were 226 million BTU of solar energy collected and 220 million BTU of solar energy used. This level of performance amounts to 404 BTU/ft^2-day versus a good performing NSDN site, Cathedral Square, which delivered only 267 BTU/ft^2-day to the loads. The measured solar fraction was 36%. Fossil fuel energy

savings were 366 million BTU at an assumed boiler efficiency of 60%. The energy flow diagram is depicted in Figure 18.

Table 8. SOLAR SYSTEM THERMAL PERFORMANCE

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 1985

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED (SECA)	SYSTEM LOAD	SOLAR ENERGY USED (SEL)	AUXILIARY ENERGY FOSSIL (AXF)	AUXILIARY ENERGY THERMAL (AXT)	SOLAR OPERATING ENERGY (SYSOPE1)	ENERGY SAVINGS FOSSIL (TSVF)	ENERGY SAVINGS ELECTRICAL (TSVE)	SOLAR FRACTION % (SFR)
DEC	15.3E	88.4E	14.3E	117	77.9	0.79E	23.8	-0.79E	16E
JAN	14.3E	80.7	14.8	98.5	65.6	0.89	24.7	-0.89	18
FEB	25.8	80.	24.2	80.0	53.3	1.00	40.3	-1.00	30
MAR	41.9E	92.6E	39.0E	80.3E	53.5E	1.03E	65.0E	-1.03E	42E
APR	41.6E	87.0E	40.9E	57.2E	38.1E	1.46E	68.2E	-1.46E	47E
MAY	45.2	80.7	45.9	56.2	37.4	1.66	76.5	-1.66	57
JUN	41.5	92.7	40.5	82.0	54.6	1.63	67.5	-1.63	47
TOTAL	226E	603E	220E	571E	380E	8.46E	366E	-8.46E	-
AVERAGE	32.3E	86.1E	31.4E	81.6E	54.3E	1.21E	52.3E	1.21E	36E

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

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

E denotes values that were estimated when there was less than 90% but more than 40% measured data.
See Appendix B for the bridging methodology used.

7. <u>F-Chart Comparison</u>. A comparison of the measured system performance versus an F-Chart (Version 5.5) model is presented in Table 9. Predicted values are the expected system performance values from Table 1. Values used in the "extrapolated" column of Table 9 were obtained by use of an F-Chart model 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 F-Chart data are given in Appendix F. The F-Chart input parameters used to extrapolate annual performance are given in Table F-2, Appendix F. The F-Chart model results are presented in Table 10. The F-Chart extrapolated prediction of solar energy used was 362 million BTU.

For the seven month monitoring period the F-Chart extrapolated value was 196 million BTU of solar energy used versus the measured value of 220 million BTU of solar energy used. This F-Chart extrapolated value is 11% below the measured valve but given the uncertainties in the measured quantities, this agreement seems acceptable. The parameters of storage UA and heat exchanger effectiveness were changed to determine if the F-Chart model could achieve a better fit to the measured values. A storage UA of

Solar Collector Efficiency	33%
Solar Collector COP	27%
Storage Efficiency	98%
Solar Energy Utilization	97%
Demand Solar Fraction	41%

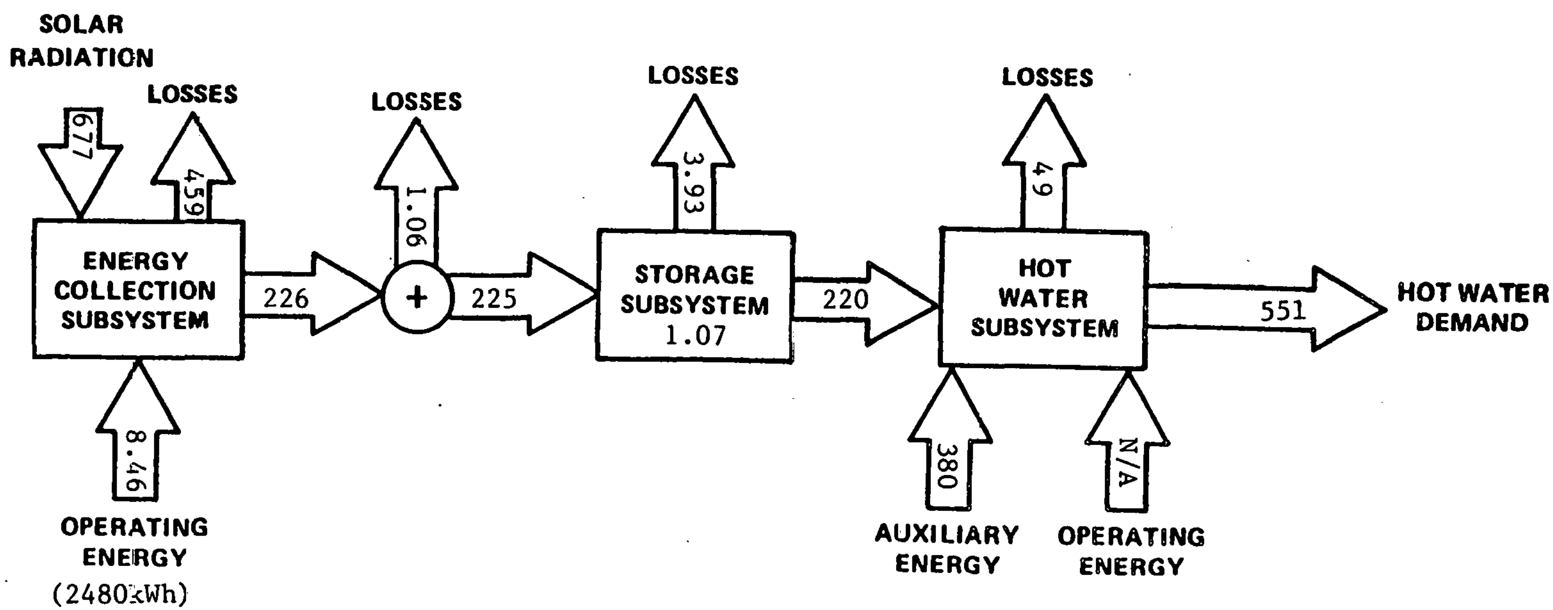


Figure 18. Energy Flow Diagram for Fort Devens Launderette
December 1984 through June 1985
(All values in million BTU, unless otherwise indicated)

Table 9. COMPARISON OF PREDICTED TO MEASURED ANNUAL PERFORMANCE FORT DEVENS LAUNDERETTE

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	MEASURED COLLECTED SOLAR ENERGY	SOLAR ENGERY USED			SOLAR FRACTION (%)		
			PREDICTED	EXTRAPOLATED	MEASURED	PREDICTED	EXTRAPOLATED	MEASURED
JAN	60	23.8E	17.9	14.7	14.8	22	18	18
FEB	84	30.8	26.4	21.9	24.2	33	27	30
MAR	124	33.8E	41.0	34.3	39.0E	44	37	42E
APR	119	35.0E	40.0	34.1	40.9E	46	39	47E
MAY	126	35.8	44.5	38.6	45.9	55	48	57
JUN	111	37.4	44.7	39	40.5	48	42	49
JUL	132	-	49.4	43.3	-	56	49	-
AUG	120	-	46.1	40.1	-	52	45	-
SEP	109	-	42.3	36.2	-	49	42	-
OCT	93	-	35.1	29.7	-	39	33	-
NOV	55	-	19.5	16.4	-	23	19	-
DEC	53	28.9E	16.7	13.8	14.3E	20	16	16E
TOTAL	1186	22.6	424	362	220	-	-	-
AVERAGE	98.8	32.2E	35.3	30.2	31.4E	41	35	37E

E denotes an estimated value when there was less than 90% but more than 40% measured data. See Appendix B for the bridging methodology used.

Table 10. F-CHART EXTRAPOLATED ANNUAL PERFORMANCE FORT DEVENS LAUNDERETTE

*** GENERAL SOLAR HEATING SYSTEM ***
** FLAT PLATE COLLECTOR **

	SOLAR MMBTU	LOAD MMBTU	QTANK MMBTU	AUX MMBTU	F
JAN	60.1	80.6	0.57	65.9	0.18
FEB	83.8	80.6	0.65	58.7	0.27
MAR	124.0	92.7	0.92	58.4	0.37
APR	119.0	87.0	0.82	52.9	0.39
MAY	126.0	80.6	0.75	42.0	0.48
JUN	111.0	92.7	0.46	53.7	0.42
JUL	131.6	89.0	0.72	45.7	0.49
AUG	119.5	89.0	0.69	48.9	0.45
SEP	109.1	86.1	0.66	49.9	0.42
OCT	92.3	89.0	0.60	59.3	0.33
NOV	54.7	86.1	0.40	69.7	0.19
DEC	53.0	84.9	0.43	71.1	0.16
YR	1184.1	1038.3	7.68	676.1	0.35

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

LOAD is the monthly hot water load on the system (MMBTU).

QTANK is the monthly total energy loss from the storage tank (MMBTU).

AUX is the monthly total auxiliary energy which must be supplied to the hot water load (MMBTU).

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

225 BTU/hr-°F ft^2 gives the correct storage losses although it is only 36% of the theoretical storage loss value. The reason for this is not known.

Adjusting the heat exchanger effectiveness to .5 and then to 1 resulted in only a 10 million BTU increase in the difference between F-Chart and measured solar energy used. Since F-Chart appeared to be relatively insensitive to the collector heat exchanger effectiveness, it was decided to leave the heat exchanger effectiveness as measured at 0.32. F-Chart appears to provide a conservative estimate of solar energy used when the measured $F_R(\tau\alpha)$ and F_R (U_L) parameters are used.

8. Energy Savings. The Energy Savings performance of the solar system is presented in Table 11. There were significant fossil fuel savings of 366 million BTU during the seven month monitoring period. There was an electrical operating expense of 8.46 million BTU. The fossil fuel savings were calculated at a 60% boiler efficiency rather than the measured 67% boiler efficiency. The use of 60% boiler efficiency permits comparison to other SFBP and National Solar Data Network sites.

TABLE 11. ENERGY SAVINGS

FORT DEVENS LAUNDERETTE
DECEMBER 1984 THROUGH JUNE 1985

(All values in million BTU)

MONTH	SOLAR ENERGY USED (SEL)	DOMESTIC HOT WATER ELECTRICAL (HWSVE)	DOMESTIC HOT WATER FOSSIL FUEL (HWSVF)	COLLECTOR OPERATING ENERGY SOLAR-UNIQUE (CSOPE)	NET ENERGY SAVINGS ELECTRICAL (TSVE)	NET ENERGY SAVINGS FOSSIL FUEL (TSVF)
DEC	14.3E	N/A	23.8E	0.79E	-0.79E	23.8
JAN	14.8	N/A	24.7	0.89	-0.89	24.7
FEB	24.2	N/A	40.3	1.00	-1.00	40.3
MAR	39.0E	N/A	65.0E	1.03E	-1.03E	65.0E
APR	40.9E	N/A	68.2E	1.46E	-1.46E	68.2E
MAY	45.9	N/A	76.5	1.66	-1.66	76.5
JUN	40.5	N/A	67.5	1.63	-1.63	67.5
TOTAL	220E	N/A	366E	8.46E	-8.46E	366E
AVERAGE	31.4E	N/A	52.3E	1.21E	-1.21E	52.3E

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 values based on less than 90% but more than 40% measured data. See Appendix B for the bridging methodology used.

The total system normalized cost was \$85,106 or \$33.30 per ft^2 of collector, (Reference 14). This represents a cost of \$235 per million BTU. The normalized cost represents an extrapolation of the actual cost to construct the system. The costs are calculated 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. The actual system cost was $240,772 or $93.94 per square foot. This solar system had the lowest normalized cost per square foot of all the monitored SFBP sites. On the other hand, the actual cost was among the highest. From the viewpoint of lower cost, this system has short pipe runs and only one pump. Also, the controller is simple with only one pump to control. The high cost items in this system are the collector support structure which extended well beyond the roof and the storage tank and special building constructed for the storage tank. Additionally, the storage tank had a special phenolic lining, 2 immersion heat exchangers and was ASME pressure rated at 125psi. For some unknown reason, the extensive structural support system was moderately priced in the normalized cost calculation.

By using the 1985 NBS Energy Price Handbook (Reference 15) for Region 1, which includes Massachusetts, an estimate of the dollar energy savings is possible. During the seven month monitoring period, the solar energy system saved 220 million BTU. At an assumed boiler efficiency of 60%, this is 367 million BTU or 359,125 cubic feet of natural gas. The savings amount to $2303 at $6.28 per million BTU. There were 8.46 million BTU or 2480 kWh of electrical operating energy used during the monitoring period. At $26.06 per million BTU, operating costs were $220. The net savings were $2083. The F-Chart extrapolated annual energy savings were 362 million BTU which amounted to 603 million BTU of fossil fuel savings. These were valued at $3789. Extrapolated annual operating costs were calculated by dividing the annual solar energy used (362 million BTU) by the system COP of 26 which results in 13.9 million BTU of operating costs. This is equivalent to 4078 kWh of electricity which would cost $363 at a cost of $26.06 per million BTU. The net extrapolated annual savings were $3426 or $1.34/ft^2 of collector.

9. System Availability. The solar system was available for 100% of the time during the monitoring period. There were some shutdowns of the auxiliary boilers. During February 1985, the gas boiler was shut down a day for adjustments. Then, during May 1985, a cracked tube was discovered in the oil fired boiler and it was shut down for the summer.

B. RELIABILITY AND MAINTAINABILITY

1. Solar Component Failure. No components of the solar system failed during the monitoring period.

2. Maintenance Time/Month. This system typically has no requirement for monthly maintenance. Probably a realistic maintenance frequency is about 4 hours every six months.

C. HARDWARE AND INSTRUMENTATION PROBLEMS

1. Hardware Problems. There were no system hardware failures during the monitoring period. However, there were several problems which degraded system performance.

There is a difference of 12 percentage points between the measured collector efficiency $F_R(\tau\alpha)$ and the ASHRAE single panel test. The factors which cause this amount of difference were investigated and the results are presented in Table 12. Most of the difference between the single panel test and the measured $F_R(\tau\alpha)$ is due to sensor error. The other differences are typical.

The measurement error was due to the sensors used to calculate the collected solar energy. On this site there was significant sensor drift indicated by the post calibration of all four of the collector loop sensors. Sensor T100, collector inlet drifted 1.3°F, sensor T150 collector outlet drifted 1.2°F, sensor T101 storage outlet drifted 0.8°F and sensor 151 storage inlet drifted 1.0°F.

Flow imbalance effects were estimated from temperature measurements made at the midpoint of eight panels on a bright, sunny August day. The measurements indicated a range in temperature rise across individual panels of 1.3°F to 17.7°F. The panels represented the outer panel and middle panel of subarrays 1, 2, 3 and 6. There are 18 panels connected in parallel via internal manifolds in each subarray. The measurements were used to calculate the individual panel U_L losses using equations 6.4.7, 6.4.8, 6.4.9 and 6.4.10 from Solar Engineering of Thermal Processes (Reference 10). Utilizing an estimated insolation value of 300 BTU/hr-°F-ft^2, measured ambient temperature, measured inlet temperature and the F_RU_L product of 0.714 from the ASHRAE test, the transmitted energy to the collector was determined. The losses were subtracted from the transmitted energy to estimate the net energy collected by each panel. The average flow rate per panel was determined from the measured total flow rate. An estimate of flow rate per panel was determined from the calculated panel net energy collected and twice the measured temperature rise (since the temperature rise was measured at the midpoint of the collector). By inspection it was noted that one panel had a flow rate similar to the average array flow rate per panel. The temperature rise for this panel was adjusted slightly to account for the

Table 12. ESTIMATED IMPACT OF FACTORS CAUSING DIFFERENCE BETWEEN SINGLE PANEL AND COLLECTOR ARRAY PERFORMANCE,

FORT DEVENS LAUNDERETTE
(percent of incident)

Measured Intercept	59%
Measurement Error	7.3%
Flow Imbalance	2.6%
Glycol Fluid Effects	1.5%
Array Pipe Losses	.6%
Dust or Dirt on Glazing	0
Total Intercept	71%
Total ASHRAE Intercept	71%

flow rate difference and the values used to determine an average net energy collected per panel. This average net energy collected per panel represents the energy collected with no flow imbalance among panels. The preceding value was compared to an average of the eight measured panel net energies collected. The difference of 2% to 3% is attributed to flow imbalance.

The array pipe losses were calculated from the array inlet and outlet temperatures and the ambient temperature. The pipe UA values were determined from the value for polyisocyanurate insulation given in the ASHRAE Fundamentals for the thickness used at the site. The reported effect of 0.6% of incident solar energy on the intercept is strictly for the theoretical calculation. In general a multiplier of 1.5 to 3 times the theoretical calculation should be used to account for uninsulated sections of pipe, pipe hangers, etc. The choice of the multiplier to use is left to the reader.

The effects of propylene glycol fluid in the array (for freeze protection) versus water which was used in the ASHRAE test were estimated by calculating the heat removal coefficient (F_R). The equation for F_R was taken from Solar Engineering of Thermal Processes, equation 6.7.4. To calculate the heat removal coefficient (F_R), equations for U_L losses (6.4.7, 6.4.8, 6.4.9 and 6.4.10), collector fin efficiency (6.5.11) and collector efficiency factor (6.5.17) were also evaluated. The collector U_L losses were calculated at average plate temperatures of 104°F and 145°F and an eyeball average of these U_L's was used in subsequent calculations. The heat removal factor was calculated with the test flow rate of 0.5 gpm per panel and water heat transfer fluid versus the average measured flow rate of 0.83 gpm. The difference due to propylene glycol was 1.5% of incident solar energy using a laminar flow heat transfer coefficient or 0.2% using a turbulent flow heat transfer coefficient. In either case, the difference between propylene glycol and water is not large because the measured flow rate is 66% greater than the test flow rate. The panel flow rate was calculated for the eight measured panels. As a quick check to determine whether flow was laminar or turbulent the Reynolds number was calculated for each flow rate. One panel was in the turbulent range, three panels were in the transition state and four panels were well within the laminar range. Since the test was done during August, when solar temperatures were relatively high and only one panel was in the turbulent range, it seems safe to say that the majority of the collector panels were flowing with laminar flow most of the rest of the year. Therefore, the propylene glycol effect is about 1.5%.

The impact of the heat exchanger effectiveness on system performance can be calculated from the same equation used to determine the heat exchanger effectiveness:

$$\text{HXEFF} = \frac{T_{OUTLET} - T_{INLET}}{T_{INLET} - T_{TANK}}$$

The average inlet and outlet temperatures of the collector were 97.5°F and 100.6°F respectively for the seven months of monitoring. Although the tank temperature was measured, the values in the tables are for the entire 24-hour day, so the equation above and measured HXEFF or 0.32 is used to estimate the seven month average tank temperature of 89.1°F when the collector pump is on. If we now assume a heat exchanger effectiveness of 0.6, the new calculated inlet temperature is 96.3°.

The impact of the new slightly lower, collector inlet temperature can be determined from the collector efficiency equation:

$$\eta = F_R(\tau\alpha) - F_R(U_L) \times \frac{T_{in} - T_{ambient}}{\text{Insolation}}$$

For the seven month monitoring period, the average insolation during collector operation was 199.2 BTU/ft^2-hr and the average ambient temperature during collector operation was 51.2°F. The measured $F_R(\tau\alpha)$ is 0.59 and the measured $F_R(U_L)$ is 0.68, so the collector operational efficiency would become 43.6% versus the measured value of 41.5%. This would result in 11.4 million BTU more collected solar energy during the seven months or a new collector efficiency of 35% versus the measured 33%. The increase in collected energy resulting from the improved heat exchanger effectiveness is relatively small.

2. <u>Instrumentation Problems</u>. There was one significant SDAS problem which occurred in early December before the newer Mod 2A was installed December 12, 1984. There were three months, December, March and April, when more than 10% of the data was lost. These values are marked with an "E" in the seasonal performance tables. In December, 65% of the data was collected; in March 82%, and in April 89% of the data was collected. The SDAS failed for unknown reasons in late January and was subsequently repaired on January 28, 1985.

In December 1984, T100 was replaced to try to correct an apparant bias error. The register on WT350 was changed from 0 to 100 gallons to a 0 to 10 gallons to provide better resolution.

In late January 1985, T001 was moved away from the path of a dryer vent discharge. Sensor T320 was moved to the correct pipe and a room temperature sensor was installed in the storage room. Sensors T100 (collector inlet), T101 (storage outlet), T150 (collector outlet) and T151 (storage inlet) were bath tested. Sensor T100 was determined to be correct, but biased by the way it was placed in the pipe. Sensor T100 was insulated better but this did not remedy the bias problem. Consequently, solar energy collected was calculated with T101 and T151 to reduce the error.

The temperature sensors and flow meter which were supposed to measure auxiliary hot water thermal energy never worked correctly. The reason, during December and January, was because a temperature sensor was in the wrong pipe. However, after January the auxiliary hot water thermal energy was still much too small to be believable when compared to the auxiliary fossil fuel used. The auxiliary thermal energy was estimated from the measured 67% boiler efficiency.

Since the auxiliary thermal energy could not be measured, the hot water load also had to be estimated. This quantity was estimated from the standby losses which occurred in late December. The average hourly value (10,280 BTU/hr) was added to the hot water demand for each hour (for this site, use of a constant value for stand by losses is possible since there was little change in the ambient temperature in the utility room). This estimate of standby losses agreed within 11% of two later measured standby loss rates.

D. SIGNIFICANT EVENTS

Below is a summary of key events at the Fort Devens Launderette solar site during the monitoring period.

Date	Event
July 18, 1983	ETEC Acceptance Test
October 24 to 28, 1984	SDAS and instrumentation checkout
November 26 and 27, 1984	SDAS repaired. Noted that T320 was in the wrong place and that T201, T202 and T203 were uninsulated.
December 10 to 12, 1984	SDAS replaced with MOD IIA SDAS. T100 was switched with T320. Replaced the register on WT350 with a 0-10 gallon size.
January 28 and 29, 1985	SDAS repaired. T001 moved out of the discharge of the dryer vent. T320 moved to the correct pipe and a surface sensor was installed. Check sensors T100, T101, T150 and T151 in a controlled temperature bath test. Insulated T100. Installed T600, the storage room ambient.
February 5 and 6, 1985	Auxiliary boilers out of service from 10:00 a.m. on February 5 until 10:00 a.m. on February 6.
March 8, 1985	SDAS failed to answer. Site personnel reset it on March 10.
March 11 to 19, 1985	After SDAS was reset all flow meters were reading out of range because the SDAS gain was lost.
March 30 and 31, 1985	SDAS failed and site personnel reset it.
April 22 to 24, 1985	SDAS failed. Reason unknown.

SIGNIFICANT EVENTS (Continued)

Date	Event
May 2 and 3, 1985	Auxiliary oil boiler shut down. Analyst noticed that flow meter WT300 was registering flow data at night when the laundry was closed, the hot water sink valve was stuck. The tempering valve was set to its minimum position of 130°F but the leak on the valve stem was not repaired.
May 6, 1985	Gas boiler reset to 130°F high temperature limit. The oil boiler was shut down because of a cracked tube. It was down all summer.
August 5 and 6, 1985	Removed SDAS and critical instrumentation. A number of sensors were bath tested; these are: T100, T101, T150, T151, T250, T300, T320, T350, T351 and T360. I001, WT300 and W100, along with the temperature sensors listed above, were returned for post calibration. The collector array was checked for balanced flow.

Section VI

COMPARISON TO PREVIOUS NSDN SITES

The SFBP solar systems are compared to previous NSDN solar systems to determine if the solar technology utilized during the SFBP program has improved solar system performance. The Fort Devens SFBP site is compared to the Cathedral Square solar system in Burlington, Vermont and an average of 6 commercial DHW solar systems from the 1981-1982 Comparative Report of NSDN solar systems (Reference 16). While comparison of the performance of this SFBP solar system to that of an NSDN solar system 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. There were three process-hot-water solar systems, an office building, a school and an apartment building. The NSDN average is represented by these six commercial systems.

The Cathedral Square collector array is composed of 80 Daystar collectors, totaling 1,798 square feet. Freeze protection is provided by a 67% propylene-glycol/water solution. Solar heated hot water is provided to a 10-story, 101-unit apartment building. Gas-fired auxiliary boilers provide backup DHW heating. The Cathedral Square solar system differs from the Fort Devens solar system in the solar DHW delivery part of the system. DHW supply water in the Cathedral Square system is heated via shell and tube heat exchangers; DHW supply water is heated in the solar storage tank in the Fort Devens solar system.

Table 13. NSDN PERFORMANCE COMPARISON

	FORT DEVENS (Dec 84-Jun 85)	CATHEDRAL SQUARE (Oct 81-Sep 82)	NSDN[1] AVERAGE (Sep 81-Dec 82)
Total Collector Array Efficiency (%)	33	32	21
Operational Collector Array Efficiency (%)	41	41	34
Percent of Incident Solar Energy Delivered to the Load (%)	32.5	26	15
Collector Coefficient of Performance (COP)	27	35	29
System Coefficient of Performance (COP)	26	17	6.7
Percent of Collected Solar Energy Delivered to the Load (%)	98	82	71
Solar Energy Delivered to the Load per Square Foot of Collector Area per Day (BTU/ft^2-day)	404	267	217

1. Eros Data Center, Oakmead Industries, Cathedral Square, Wood Road School, Craftsman Enterprises and Vitro Test Site.

Table 13 presents the performance data for Fort Devens, Cathedral Square and the NSDN average. Fort Devens performed better than Cathedral Square or the 1982 NSDN average commercial solar system in nearly all categories except collector COP. The collector COP is somewhat lower at Fort Devens because of the high flow rate. Note that the collector subsystem performance is very nearly the same for Fort Devens and Cathedral Square. However, there is substantially better utilization of solar energy at Fort Devens because the DHW supply water is heated as it flows through the solar storage tank. Solar energy utilization was also high at Fort Devens because the solar energy was used as it was being collected. In fact, usually the collected solar energy was exhausted by about 8:00 p.m. each day. (This was determined by noting the time when the storage temperature in the evening equaled the morning startup temperature.) Cathedral Square had a lower solar energy utilization because the load timing was such that the greatest loads occurred during the late evening and early morning hours.

One can conclude that the SFBP solar collectors at Fort Devens performed similarly to the better NSDN collector systems and significantly above the average NSDN DHW system. The Fort Devens solar system was better integrated into the DHW system and it out performed the NSDN solar systems in terms of solar energy utilization.

Section VII

LESSONS LEARNED

There were several lessons learned at Fort Devens; perhaps these lessons learned should be called lessons in good engineering practice. Basically, the Fort Devens solar system performed very well so the lessons learned are of the more positive form, "Here's how to design a solar system right!"

o The primary "good engineering practice" which should be praised is the use of a simple solar energy collection and delivery to load system with almost immediate use of the solar heated water. This collector array requires only a temperature differential controller and no system interface controller. The result of this design is high solar energy utilization.

o The propylene glycol antifreeze solution is a required component of this system. Since propylene glycol has a lower heat capacity, there is a small reduction in collector efficiency. The reduction in efficiency at Fort Devens was estimated to be only 2-1/2%. This reduction was minimized by the 75% increase in flow rate over the 0.022 gpm/ft^2 rule of thumb. The poorer propylene glycol heat transfer properties should be compensated for by a larger flow rate.

o There is also another effect on collector efficiency when using a more viscous fluid than water. This is the effect of flow rate and fluid characteristics on the heat transfer coefficient between the riser tube and the fluid. At Fort Devens, the propylene glycol was usually at a flow rate and temperature which would result in laminar flow and therefore a lower heat transfer coefficient. The effect on collector efficiency was small.

o There was some flow imbalance within collector subarrays at Fort Devens. Fortunately, good design practice reduced the flow imbalance effects to 4% of the measured collector $F_R(\tau\alpha)$. The installer used variable sized orifices in the inlet and outlet header connections to reduce the flow imbalance between panels.

o The storage tank loss coefficient was similar to the theoretical calculated heat loss rate. This good storage performance is attributed to the high utilization of solar energy which reduced storage temperatures quickly and the entry of cold supply water at the bottom of storage which served to limit saddle losses. Thermosiphoning to the collector array did occur and accounts for the higher quiescent tank loss rate.

o Perhaps the least effective component in the solar system was the immersed heat exchanger. The immersed heat exchanger effectiveness was lower than expected which caused higher collector plate temperatures. This problem may have been mitigated somewhat by the load timing and cold supply water entering the tank near the heat exchanger.

- To maximize the collector area that could be placed on the roof, the designer spaced the rows of collectors so that there was about 10% self-shading in December. The net result was an increase in total solar energy collected over the year when compared to a roof of comparable area and no collector self-shading.

- The solar storage tank is oversized for this system where loads occur concurrently with solar energy collection. The results of an F-Chart analysis indicates that a 1500 gallon tank will supply more solar energy to the load than the present 3800 gallon tank. AN ETEC study (reference 12) shows that the smaller tank would have been more cost effective.

- The collector support structure which overhangs the roof is not necessarily cost effective because of its high cost. A collector array mounted on the existing roof area would be more cost effective.

- The F-chart model appears to underpredict solar energy utilization for this solar system. A good agreement on storage losses was obtained with a storage UA only 36% of theoretical.

Section VIII

OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

A. OBSERVATIONS

An external heat exchanger may improve collector performance because of better heat exchanger effectiveness. An external heat exchanger may also improve solar energy used. However, it must be determined if the manufacturer's stated effectiveness can be obtained and whether an immersion or external heat exchanger is more cost effective.

A system with large daytime loads will probably have higher solar utilization than a system with evening or morning loads. Likewise, when sizing the storage tank for a system with large daytime loads, the designer can reduce the storage volume to 0.5 gallons per square foot and still have good performance. In fact, F-chart indicates an improvement in performance and the smaller storage tank should result in a significant reduction of the system cost.

The large structure required to extend the roof area for collector support should be avoided. Intuitively, use of the existing roof structure is more cost effective.

The system was not cost effective no matter whether the normalized or actual cost was used as a basis. At current fuel costs and using normalized cost, it would require 25 years to payback the initial cost of the system without considering interest costs.

Flow balancing with a set of staged orifices is adequate as the manufacturer suggests. However, additional flow balancing valves between each row of the array might reduce the row to row temperature differences.

Use of a drainback system instead of an antifreeze system may be better for a new sytem with a similar application. A drainback system offers the advantage of no antifreeze cost or maintenance and an improvement in collector array efficiency resulting from using water as the collection fluid. No savings on the collector pump or operating costs would be anticipated.

The boilers could be shutdown during holidays to save fuel. An overnight shutoff would not have saved much fossil fuel at Fort Devens because the auxiliary system did not run between 2100 hours and 0600 hours.

The boiler temperature and the tempering valve setpoint were lowered with the expectation of saving energy. This is still expected although energy savings could not be verified because the boiler recirculation pumps began to run continuously.

Since this was a first attempt at integrating a solar system on a laundry by the designer of the Fort Devens system, it is regarded as a prototype system. An application of the lessons learned from this system should improve the design and implementation of future solar energy systems.

A suggested improved design for this application is shown in figure 19. The heat exchanger would be moved outside the storage tank and have an improved effectiveness of 0.7. The storage tank would be sized at 1500 gallons to obtain better storage optimization. The net gain of these changes are estimated by F-Chart to be 15.1 million BTU more solar energy used. There would be a cost savings on the storage tank but other system costs would be expected to remain the same. The net annual energy savings would improve slightly to $3,571 or $1.39/ft^2.

The design review committee recommended that check valves be installed where a reverse temperature gradient might occur. Unfortunately, the designer overlooked this recommendation because there was no check valve called out on the piping schematic for the collector return. The design review team should have specifically requested a check valve on the collector return. Apparently a lift of 21½ feet is enough to cause thermosiphoning, even with the small temperature gradients that existed at Fort Devens.

B. CONCLUSIONS

The solar energy system at Fort Devens performed well. Good performance can be attributed to good matching of solar output to load, reliable system components, a simple controller and professional installation of the collector array and storage tank. The storage tank and piping were well insulated.

The fact that collector array performance did not match the ASHRAE single panel performance was disappointing. The reduction in performance was due to several causes, collector flow imbalance and glycol fluid properties among the primary causes. Eliminating glycol antifreeze would require the use of a drainback system. Reducing the effects of flow imbalance, pipe losses, etc. might be too costly to eliminate even for new construction.

The storage tank immersed heat exchanger also reduced collector array performance. If antifreeze solutions are used, the designer should evaluate the type, cost and effectiveness of the heat exchanger carefully. The use of more immersed heat exchange surface may not result in improved performance and may not be cost effective.

The introduction of DHW supply water into the bottom of storage reduced saddle losses, reduced collector inlet temperatures and improved performance of the immersion heat exchanger. This also effectively combined the storage and preheat tank which resulted in good solar energy utilization and reduced the need for control of the solar and auxiliary interface. Another result was a reduction in maintenance due to system simplicity. This aspect of the Fort Devens solar system design is commended.

Propylene glycol freeze protection worked well. The designer was able to compensate for the lower heat capacity by a higher flow rate. Some loss of collector array efficiency and a greater pumping cost occurred due to the viscosity of the propylene glycol mixture. The reduction of collector efficiency appears to be due to a lower heat transfer coefficient in the collector riser tubes caused by laminar flow of the collector fluid.

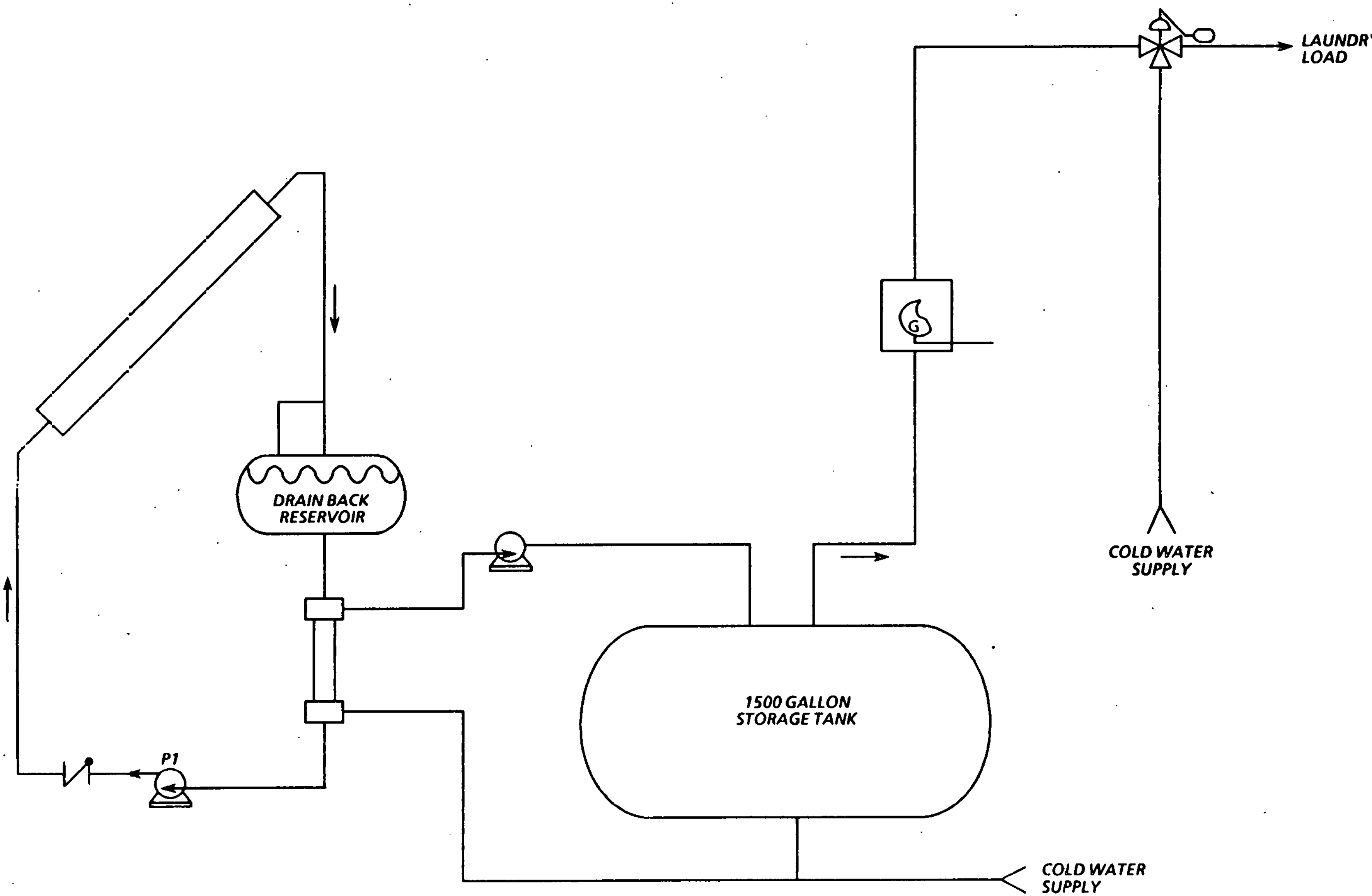


Figure 19: Schematic of Fort Devens Launderette Solar System Optimum Configuration

The F-chart General Solar Heating model tended to underpredict the solar energy used. However, the General Solar Heating model was much better for modeling the loads and storage losses than the Hot Water Heating model. The reasons that loads and losses were modeled well is that the General Solar Heating model has a constant load profile and the storage loss rate is an input parameter. Knowing the loads accurately, allowed the General Solar Heating model to be used to predict that a smaller storage (1500 gallons) would provide more solar energy used.

C. RECOMMENDATIONS

For a new system with a similar application a drainback system would eliminate the need for antifreeze which caused about a 2-1/2% decrease in collector efficiency. A smaller pump might be utilized since the flow rate could be reduced. There would also be another small improvement in collected energy of 2.2% due to a reduction in collector heat capacity losses. In addition to the almost 5% improvement in collector efficiency, the elimination of propylene glycol may reduce cost. System complexity would not increase.

Insulate the storage tank saddle, pump, and piping near the pump. Storage losses could be reduced by almost 50% with this insulation. Potentially much greater losses may be occurring with the thermosiphoning to the collector array. These losses may be reduced or stopped by installing a check valve in the collector return pipe near the heat exchanger. A more adequate method of stopping thermosiphoning would be to install a "U" shaped drop in the collector return piping from the floor to ceiling of the storage room.

Row to row collector flow balancing would improve collector array performance. Flow balancing valves between each row could serve this purpose. These would force more flow through the rows farthest from the pump. The last rows ran at larger operating points due to the lower flowrate.

In future construction, solar system structural costs could be significantly reduced if the collector area had been restricted to the existing roof area. The large structure which extended the roof area was costly and served only to increase the solar fraction. A smaller collector array would still save as much per square foot but be much more cost effective.

The boiler recirculation pump control setpoint needs to be changed along with the boiler and tempering valve setpoint. These pumps should only run during boiler operation. The continuously running pumps cause large boiler standby losses.

In a new design, the large (500 gallons) auxiliary storage tank should be replaced with an instantaneous water heating boiler. This would reduce standby losses and the auxiliary tank losses.

Section IX

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APPENDIX A

PERFORMANCE FACTORS AND SOLAR TERMS

A-1. GENERAL ACRONYMS

A-2. PERFORMANCE FACTOR DEFINITIONS AND ACRONYMS

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 2.928×10^{-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 (°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 = Σ 56.8833 x EP100 x 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-°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°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:

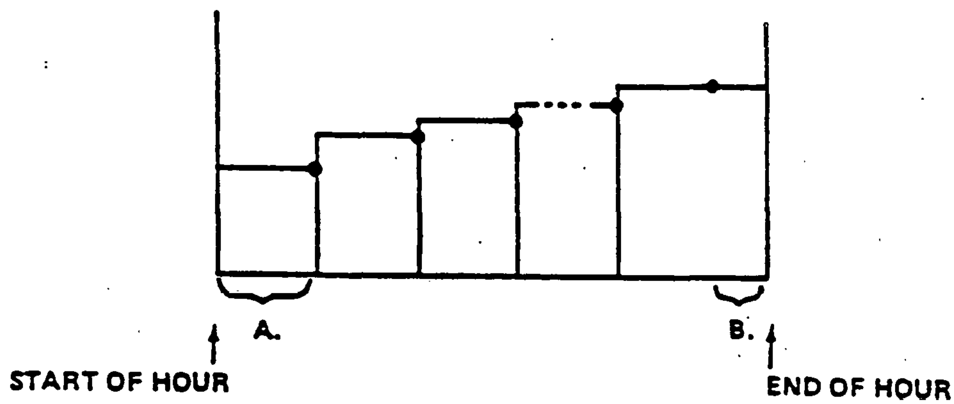


Figure 1

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.

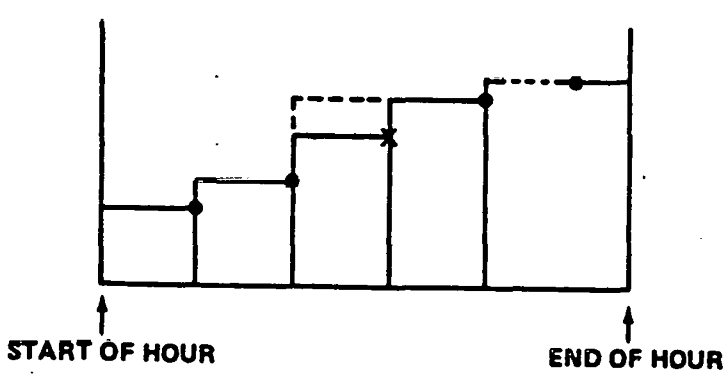


Figure 2

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

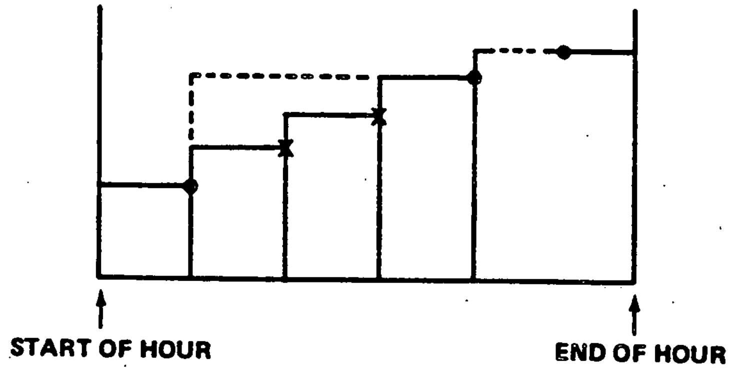


Figure 3

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

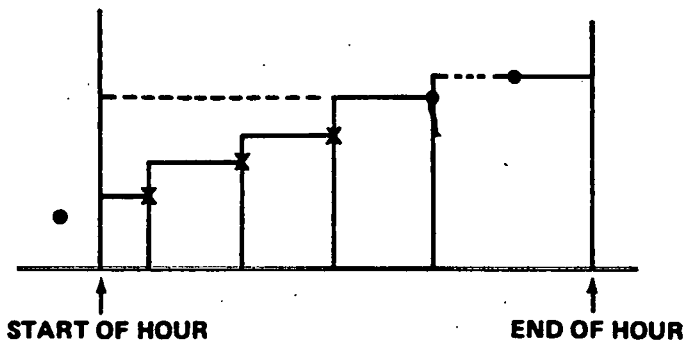


Figure 4

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).

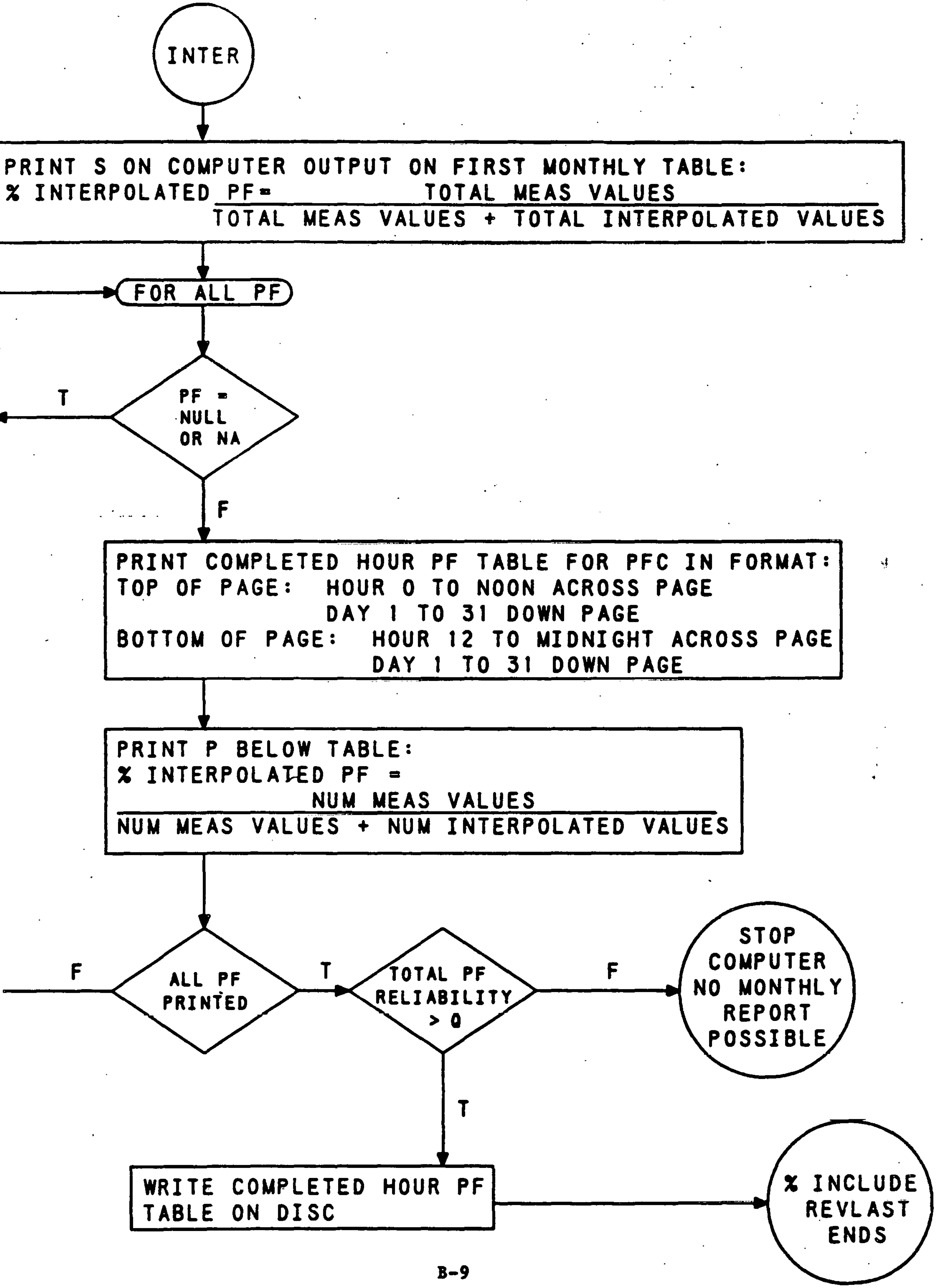
   f. I = PFFD (when no measured values available for PFPD).

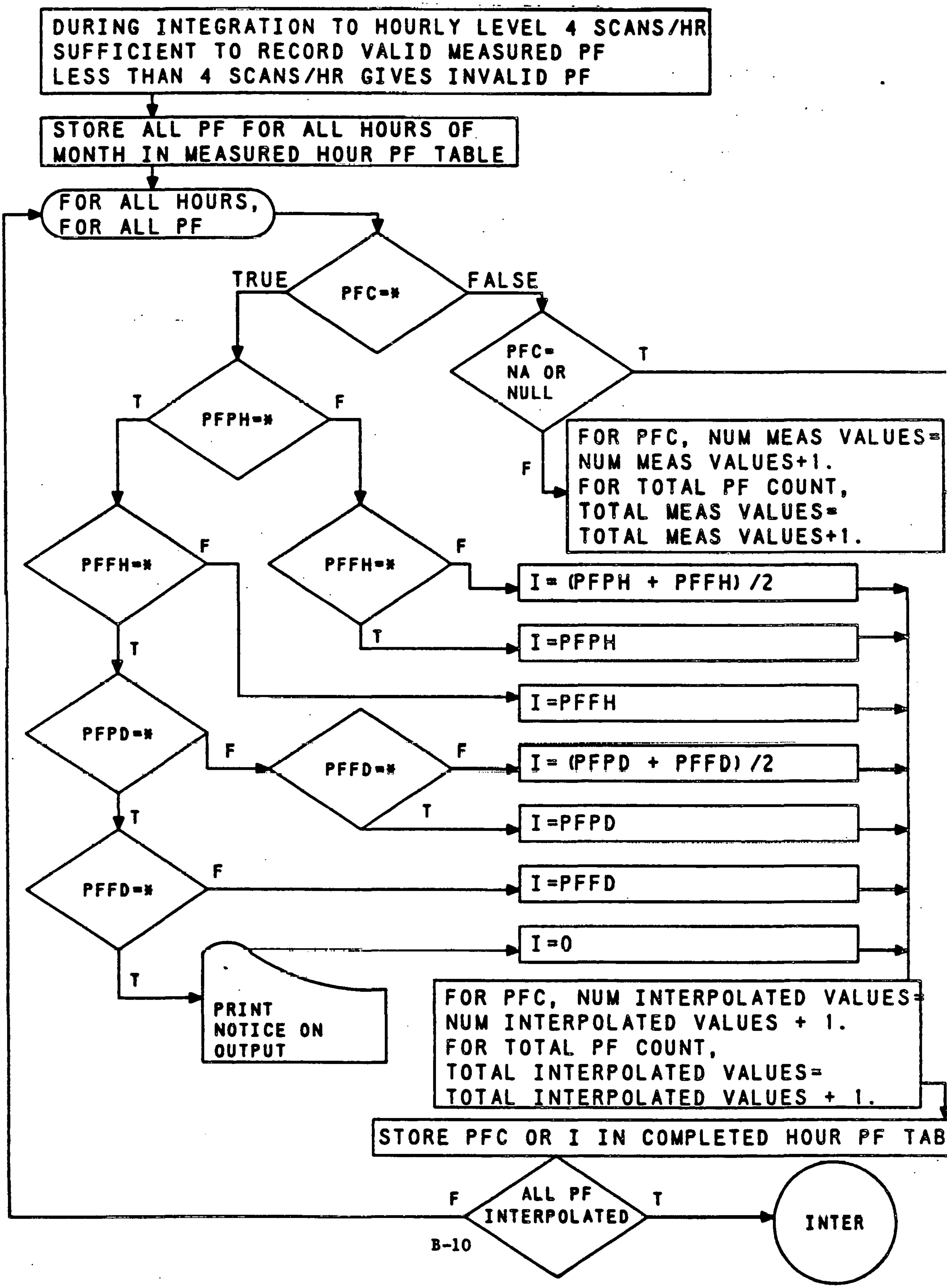
5. Non-measured performance factor values are flagged. Interpolated values are marked with a "B" on the computer output. An "X" is noted by arbitrary zero values for which no relevant measured data is available for interpolation. A number, P, is printed with each monthly performance factor where $0 \leq P \leq 1.0$ 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 3200059) Rev. Fort Devens Launderette, SFBP 1751, February 5, 1985.


INTER
PRINT S ON COMPUTER OUTPUT ON FIRST MONTHLY TABLE:
% INTERPOLATED PF = TOTAL MEAS VALUES / TOTAL MEAS VALUES + TOTAL INTERPOLATED VALUES
FOR ALL PF
PF = NULL OR NA
T
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 > 0
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
TRUE
PFC=*
FALSE
PFC= NA OR NULL
T
F
FOR PFC, NUM MEAS VALUES= NUM MEAS VALUES+1. FOR TOTAL PF COUNT, TOTAL MEAS VALUES= TOTAL MEAS VALUES+1.
PFPH=*
PFFH=*
PFFH=*
I= (PFPH + PFFH) /2
I=PFPH
I=PFFH
PFPD=*
PFFD=*
I= (PFPD + PFFD) /2
I=PFPD
PFFD=*
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

FORT DEVENS LAUNDERETTE SCAN-LEVEL EQUATIONS

WEATHER

AMBIENT MINIMUM AND MAXIMUM TEMPERATURE (°F)

TAMIN = MIN(TAMIN, T001)

TAMAX = MAX(TAMAX, T001)

AMBIENT TEMPERATURE (°F)

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

DAYTIME AMBIENT TEMPERATURE ± 3 HOURS OF SOLAR NOON (°F)

IF ABS(TIME_OF_DAY - TIME_OF_SOLAR_NOON) < 180

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

STORAGE ROOM TEMPERATURE (°F)

$TB = \Sigma\ T600 \times \Delta\tau \times (1/60)$

COLLECTOR

COLLECTOR INLET TEMPERATURE (°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)

$SEOP = \Sigma\ CLAREA \times I001 \times \Delta\tau$

where: $M100 > 0$

$CLAREA = 2{,}563\ ft^2$

SOLAR ENERGY COLLECTED (BTU)

$$SECA = \Sigma\ M100 \times CPP56W[(T100 + T150)/2] \times [(T150 + T151/2 - (T100 + T101)/2] \times \Delta\tau$$

where CPP56W is a function which calculates the enthalpy of the collector fluid (56% propylene glycol)

COLLECTOR OPERATING ENERGY (BTU)

$$CSOPE = \Sigma (EP100 \times ET100) \times 56.8833 \times \Delta\tau$$

where: EP100 = 2.34 kW (One Time Measurement)

LINELOSS - COLLECTOR INLET PIPES (BTU)

$$LINLOSCOL = \Sigma M100 \times CPP56W[(T100 + T101)/2] \times (T101 - T100) \times \Delta\tau$$

$$ALTLLOSCOL = \Sigma UACOL \times (T100 - T600) \times \Delta\tau \times (1/60)$$
(Not Calculated before Feb 85)

where: UACOL = 4.73 BTU/hr°F (based on the theoretical value of the pipe insulation)

$$*ARRAYLLOSIN = \Sigma UAIN \times (T100 - T001) \times \Delta\tau \times (1/60)$$

where: UAIN = 8.05 BTU/hr°F (based on the theoretical value of the pipe insulation in the array distribution piping)

LINELOSS - COLLECTOR OUTLET PIPES (BTU)

$$LINLOSSTO = \Sigma M100 \times CPP56W[(T150) + T151)/2] \times (T150 - T151) \times \Delta\tau$$

$$ALTLLOSSTO = \Sigma UASTO \times (T150 - T600) \times \Delta\tau \times (1/60)$$
(Not Calculated before Feb 85)

where: UASTO = 2.14 BTU/hr°F (based on the theoretical value of the pipe insulation)

$$*ARRAYLLOSOUT = \Sigma UAOUT \times (T150 - T001) \times \Delta\tau \times (1/60)$$

where: UAOUT = 7.02 BTU/hr°F (based on the theoretical value of the insulation on pipes in the array return)

STORAGE

STORAGE TEMPERATURE (°F)

$$TST = \Sigma (T201 + T202 + T203)/3 \times \Delta\tau \times (1/60)$$

*Special equation developed for this system only

ALTERNATE STORAGE INLET ENERGY CALCULATION (BTU)

$$*STEI1 = \Sigma\ M100 \times CPP56W[(T151 + T101)/2] \times (T151 - T101) \times \Delta\tau$$

STORAGE ENERGY OUT(BTU)

$$STEO = \Sigma\ M300 \times HWD(T250,\ T300) \times \Delta\tau \text{ (Dec 84 - May 85)}$$
$$STEO = \Sigma\ M350 \times HWD(T250,\ T300) \times \Delta\tau \text{ (Jun 85)}$$

HEAT EXCHANGER EFFECTIVENESS (These values are used in the hourly calculation of HXEFF to provide a weighted average of the temperature measurements)

$$EXH = \Sigma\ M100 \times (T151 - T101) \times \Delta\tau$$

$$EMAX = \Sigma\ M100 \times (T151 - T202) \times \Delta\tau \text{ when } M100 > 0$$

<u>DOMESTIC HOT WATER</u>

SUPPLY WATER TEMPERATURE (°F)

$$TSW = \Sigma\ T300 \times \Delta\tau \times (1/60)$$ (Average temperature weighted by the volume of water used.)

HOT WATER TEMPERATURE (°F)

$$THW = \Sigma\ T350 \times \Delta\tau \times (1/60)$$ (Average temperature weighted by the volume of water used.)

HOT WATER CONSUMED (GALLONS)

$$HWCSM = \Sigma\ WT300 \text{ (Dec 84 - May 85)}$$
$$HWCSM = \Sigma\ WT350 \text{ (Jun 85)}$$

TEMPERED WATER CONSUMED (GALLONS)

$$HWCSMA = \Sigma\ WT350$$

HOT WATER DEMAND (BTU)

$$HWDM = \Sigma\ M300 \times HWD(T350,\ T300) \times \Delta\tau \text{ (Dec 84 - May 85)}$$
$$HWDM = \Sigma\ M350 \times HWD(T350,\ T300) \times \Delta\tau \text{ (Jun 85)}$$

*TEMPERED HOT WATER DEMAND (BTU)

$$HWDM1 = \Sigma\ M350 \times HWD(T351,\ T300) \times \Delta\tau$$

*Special equation developed for this system only

HOT WATER OPERATING ENERGY (BTU)

$$HWOPE = \Sigma\ 56.8833 \times (EP361 + EP362) \times ET361 + EP360 \times ET360]$$

where: EP360 = 0.46 kW, EP361 = 0.18 kW, EP362 = 0.91 kW — one time measurement of power used

56.8833 = BTU/kW - min

PUMP RUN TIMES

COLLECTOR PUMP P1 (MIN)

*P1_RT = Σ ET100

AUXILIARY PUMP P2 (MIN)

*P2_RT = Σ ET360

AUXILIARY PUMP P3 (MIN)

*P3_RT = Σ ET361

COLLECTOR CONTROL (MIN)

*CTL_100 = Σ DS100 x $\Delta\tau$

VII HOURLY EQUATIONS

COLLECTOR

OPERATING POINT (°F-ft^2-hr/BTU)

OPPNT = (TIN - TA)/SE

if SE > 0

SOLAR ENERGY ON THE ARRAY (BTU)

SEA = CLAREA x SE

where: CLAREA = 2,563 ft^2

*Special equation developed for this system only

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

SEC = SECA/CLAREA

COLLECTOR EFFICIENCY (%)

CLEF = SECA/SEA x 100

COLLECTOR OPERATIONAL EFFICIENCY (%)

CLEFOP = SECA/SEOP x 100

STORAGE

ENERGY INTO STORAGE (BTU)

STEI = SECA

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 = 3,800 gallons

TST1 = the average storage temperature at the beginning of the hour

TST_P = the average storage temperature at the beginning 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 - TB)]

where: SUR_AREA = 396 ft^2

HEAT EXCHANGER EFFECTIVENESS RATIO

HXEFF = EHX/EMAX

DOMESTIC HOT WATER

SOLAR ENERGY TO THE DHW SUBSYSTEM (BTU)

HWSE = STEO

NATURAL GAS USED (ft^3)

GASVOL = F360

NO. 2 OIL USED (GALLONS)

OILVOL = F361

AUXILIARY HOT WATER THERMAL ENERGY (BTU)

HWAT = HWL - HWSE (Dec. 1, 1984 - Jan. 29, 1985)

HWAT = HWFEFF x (GASVOL x 1,021 + OILVOL x 138,690)

where: HWFEFF = 0.667 (Average of measured efficiencies for both boilers)

HOT WATER LOAD (BTU)

HWL = HWDM + 10,280

(Where 10,280 are standby losses in BTU measured on Christmas Day when there was no laundry activity)

AUXILIARY FOSSIL ENERGY USED (BTU)

HWAF = GASVOL x 1,021 + OILVOL x 138,690

HOT WATER SOLAR FRACTION (%)

HWSFR = (HWSE/HWL) x 100

if HWL > 0, otherwise HWSFR = 0

HOT WATER DEMAND SOLAR FRACTION (%)

HWDSFR = HWSE/(HWSE + HWAT) x (1 - TEMP) + (HWDSFR_P/100) x TEMP 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

HOT WATER FOSSIL FUEL SAVINGS (BTU)

HWSVF = HWSE/HWFEFF

where: HWFEFF = 0.6 (standard boiler efficiency used for all sites to permit easy comparison)

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 SAVING (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

if SYSL > 0

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. The monthly totals are the same values as those which appear in the tables in the body of this report except for values affected by an apparent bias on T100, instrumentation used to measure Auxiliary Thermal Energy used and a failure of WT300 at the end of May. These problems were resolved as follows:

1. Values for Solar Energy Collected and Solar Energy to Storage were recalculated using T101 and T151 rather than T100 and T150.

2. The combined average furnace efficiency was determined from days when no solar energy was used and Auxiliary Thermal Energy used was estimated from the amount of fuel used.

3. In June values for Solar Energy Used, Hot Water Load, Solar Fraction of Load, Hot Water Demand, Solar Fraction of Demand and Hot Water Consumption were recalculated using WT350. Since the boiler thermostat and the tempering valve had been adjusted prior to June, there was no tempering of hot water in June and this substitution gave accurate results.

The above changes were made in body of the text but not in the tables which follow.

MONTHLY REPORT: DECEMBER 1984
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3082

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	52.990 MILLION BTU
	20675 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	14.687 MILLION BTU
	5730 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	41 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.27
ECSS OPERATING ENERGY	0.789 MILLION BTU
STORAGE EFFICIENCY	102.23 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.416 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.075 MILLION BTU
TOTAL ENERGY CONSUMED	134.735 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	88.416	N.A.	N.A.	88.416 MILLION BTU
SOLAR FRACTION	16	N.A.	N.A.	16 PERCENT
SOLAR ENERGY USED	14.266	N.A.	N.A.	14.266 MILLION BTU
OPERATING ENERGY	1.287	N.A.	N.A.	2.075 MILLION BTU
AUX. THERMAL ENERGY	74.150	N.A.	N.A.	74.150 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	116.960	N.A.	N.A.	116.960 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.789 MILLION BTU
FOSSIL SAVINGS	20.380	N.A.	N.A.	20.380 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.71

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 35.45

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0304-81/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: DECEMBER 1984
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3082

	SI UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	55.904 GIGA JOULES
	234785 KJ/SQ.M.
COLLECTED SOLAR ENERGY	15.495 GIGA JOULES
	65074 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	5 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.27
ECSS OPERATING ENERGY	0.832 GIGA JOULES
STORAGE EFFICIENCY	102.23 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	2.362 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.189 GIGA JOULES
TOTAL ENERGY CONSUMED	142.145 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	93.279	N.A.	N.A.	93.279 GIGA JOULES
SOLAR FRACTION	16	N.A.	N.A.	16 PERCENT
SOLAR ENERGY USED	15.051	N.A.	N.A.	15.051 GIGA JOULES
OPERATING ENERGY	1.357	N.A.	N.A.	2.189 GIGA JOULES
AUX. THERMAL ENG	78.228	N.A.	N.A.	78.228 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	123.393	N.A.	N.A.	123.393 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.832 GIGA JOULES
FOSSIL SAVINGS	21.501	N.A.	N.A.	21.501 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.71
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 35.45

* = 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: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 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	1.730#	41#	0.461#	N	0.026#	N	0.267#
2	1.730#	41#	0.461#	O	0.026#	O	0.267#
3	1.730#	41#	0.461#	T	0.026#	T	0.267#
4	1.730#	41#	0.461#		0.026#		0.267#
5	1.730#	41#	0.461#	A	0.026#	A	0.267#
6	1.730#	41#	0.461#	P	0.026#	P	0.267#
7	1.730#	41#	0.461#	P	0.026#	P	0.267#
8	1.730#	41#	0.461#	L	0.026#	L	0.267#
9	1.730#	41#	0.461#	I	0.026#	I	0.267#
10	1.129	40	0.247	C	0.014	C	0.219
11	1.730#	41#	0.461#	A	0.026#	A	0.266#
12	0.974	41	0.148	B	0.031	B	0.152
13	2.433	54	0.563	L	0.049	L	0.231
14	0.679	36	0.520	E	0.007	E	0.765
15	0.154	31	0.190		0.000		1.233
16	0.360	37	0.053		0.000		0.146
17	2.533	54	0.724		0.044		0.286
18	2.426	52	0.782		0.039		0.322
19	0.524	42	0.261		0.001		0.497
20	2.663	44	0.571		0.039		0.215
21	0.818	32	0.352		0.003		0.430
22	1.208	43	0.329		0.028		0.272
23	3.573	42	0.901		0.050		0.252
24	3.103	43	0.392		0.044		0.126
25	3.533	36	0.003		0.037		0.001
26	2.832	31	1.738		0.033		0.614
27	0.357	21	0.442		0.000		1.239
28	0.182	32	0.115		0.000		0.632
29	1.671	70	0.593		0.047		0.355
30	1.320	51	0.396		0.021		0.300
31	3.217	38	0.335		0.044		0.104
SUM	52.990	-	14.266	N.A.	0.789	N.A.	-
AVG	1.709	41	0.460	N.A.	0.025	N.A.	0.269
PFRV	0.6452	0.6452	0.6452	N.A.	0.6452	N.A.	0.6452

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 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	1.730#	1.321#	0.479#	47#	0.277#	0.363#
2	1.730#	1.321#	0.479#	47#	0.277#	0.363#
3	1.730#	1.321#	0.479#	47#	0.277#	0.363#
4	1.730#	1.321#	0.479#	47#	0.277#	0.363#
5	1.730#	1.321#	0.479#	47#	0.277#	0.363#
6	1.730#	1.321#	0.479#	47#	0.277#	0.363#
7	1.730#	1.321#	0.479#	47#	0.277#	0.363#
8	1.730#	1.321#	0.479#	47#	0.277#	0.363#
9	1.730#	1.321#	0.479#	47#	0.277#	0.363#
10	1.129	0.857	0.306	43	0.271	0.357
11	1.730#	1.321#	0.479#	47#	0.277#	0.363#
12	0.974	0.881	0.217	36	0.223	0.247
13	2.433	2.274	0.977	61	0.401	0.430
14	0.679	0.259	0.102	36	0.151	0.396
15	0.154	0.000	0.000	31	0.000	0.000
16	0.360	0.000	0.000	40	0.000	0.000
17	2.533	2.337	1.001	60	0.395	0.428
18	2.426	2.022	0.760	65	0.313	0.376
19	0.524	0.031	-0.012	41	-0.024	-0.402
20	2.663	2.247	0.888	55	0.333	0.395
21	0.818	0.082	0.031	36	0.038	0.380
22	1.208	0.735	0.321	48	0.266	0.437
23	3.573	3.111	1.085	54	0.304	0.349
24	3.103	2.701	0.898	56	0.290	0.333
25	3.533	2.656	0.713	41	0.202	0.268
26	2.832	1.952	0.519	41	0.183	0.266
27	0.357	0.000	0.000	22	0.000	0.000
28	0.182	0.000	0.000	31	0.000	0.000
29	1.671	1.443	0.750	80	0.449	0.520
30	1.320	0.954	0.418	57	0.317	0.438
31	3.217	2.672	0.921	49	0.286	0.345
SUM	52.990	40.423	14.687	-	-	-
AVG	1.709	1.304	0.474	47	0.277	0.363
PFRV	0.6452	0.6452	0.6452	0.6452	0.6452	0.6452

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 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	0.479#	0.461#	*	63#	*
2	0.479#	0.461#	*	63#	*
3	0.479#	0.461#	*	63#	*
4	0.479#	0.461#	*	63#	*
5	0.479#	0.461#	*	63#	*
6	0.479#	0.461#	*	63#	*
7	0.479#	0.461#	*	63#	*
8	0.479#	0.461#	*	63#	*
9	0.479#	0.461#	*	63#	*
10	0.306	0.247	-0.084	58	*
11	0.479#	0.461#	-0.001	61#	*
12	0.217	0.148	-0.026	56	*
13	0.977	0.563	0.478	62	*
14	0.102	0.520	-0.349	62	*
15	0.000	0.190	-0.206	52	*
16	0.000	0.053	-0.051	48	*
17	1.001	0.724	0.433	58	*
18	0.760	0.782	0.035	67	*
19	-0.012	0.261	-0.274	59	*
20	0.888	0.571	0.394	64	*
21	0.031	0.352	-0.354	61	*
22	0.321	0.329	0.041	56	*
23	1.085	0.901	0.302	65	*
24	0.898	0.392	0.571	76	*
25	0.713	0.003	0.773	97	*
26	0.519	1.738	-1.272	93	*
27	0.000	0.442	-0.492	60	*
28	0.000	0.115	-0.112	50	*
29	0.750	0.593	0.263	55	*
30	0.418	0.396	0.052	59	*
31	0.921	0.335	0.646	70	*
SUM	14.687	14.265	0.380	-	-
AVG	0.474	0.460	0.012	63	*
PFRV	0.6452	0.6452	N.A.	0.6452	0.6452

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 1984

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	2.861#	14#	0.461#	0.041#	2.400#	N	3.799#	N	0.659#	48#	160#	2854#
2	2.861#	14#	0.461#	0.041#	2.400#	O	3.799#	O	0.659#	48#	160#	2854#
3	2.861#	14#	0.461#	0.041#	2.400#	T	3.799#	T	0.659#	48#	160#	2854#
4	2.861#	14#	0.461#	0.041#	2.400#		3.799#		0.659#	48#	160#	2854#
5	2.861#	14#	0.461#	0.041#	2.400#	A	3.799#	A	0.659#	48#	160#	2854#
6	2.861#	14#	0.461#	0.041#	2.400#	P	3.799#	P	0.659#	48#	160#	2854#
7	2.861#	14#	0.461#	0.041#	2.400#	P	3.799#	P	0.659#	48#	160#	2854#
8	2.861#	14#	0.461#	0.041#	2.400#	L	3.799#	L	0.659#	48#	160#	2854#
9	2.861#	14#	0.461#	0.041#	2.400#	I	3.799#	I	0.659#	48#	160#	2854#
10	2.649	9	0.246	0.029	2.402	C	3.202	C	0.352	48	151	2827
11	2.859#	14#	0.460#	0.040#	2.398#	A	3.705#	A	0.658#	48#	160#	2852#
12	1.756	8	0.148	0.019	1.608	B	1.923	B	0.211	48	152	1743
13	2.374	24	0.562	0.019	1.811	L	1.972	L	0.803	48	150	2492
14	3.122	17	0.519	0.035	2.602	E	2.487	E	0.742	48	149	3403
15	4.383	4	0.190	0.065	4.193		6.101		0.271	48	154	4651
16	4.237	1	0.052	0.070	4.184		6.908		0.075	47	143	5004
17	3.501	21	0.724	0.050	2.777		4.528		1.034	47	165	3328
18	3.061	26	0.781	0.047	2.279		3.815		1.116	48	162	2961
19	2.603	10	0.260	0.045	2.342		3.907		0.372	47	159	2521
20	2.526	23	0.571	0.033	1.955		3.292		0.816	47	160	2423
21	2.688	13	0.351	0.043	2.336		4.175		0.502	47	160	2599
22	3.501	9	0.328	0.060	3.172		5.230		0.469	47	156	3577
23	3.368	27	0.900	0.045	2.468		4.121		1.286	47	163	3244
24	1.391	28	0.392	0.016	0.998		1.630		0.560	47	164	1172
25	0.254	1	0.002	0.005	0.251		0.310		0.004	71	162	9
26	3.437	51	1.737	0.033	1.699		3.092		2.482	47	165	3234
27	3.573	12	0.441	0.054	3.131		5.402		0.631	46	159	3547
28	2.737	4	0.114	0.049	2.622		4.608		0.164	46	157	2687
29	4.089	14	0.592	0.078	3.496		5.891		0.846	46	160	4065
30	3.010	13	0.396	0.046	2.614		4.469		0.565	46	161	2882
31	1.534	22	0.334	0.019	1.199		1.989		0.478	47	164	1309
SUM	88.416	-	14.266	1.286	74.150	N.A.	116.959	N.A.	20.380	-	-	88234
AVG	2.852	16	0.460	0.041	2.391	N.A.	3.772	N.A.	0.657	47	158	2846
PFRV	0.6452	0.645	0.6452	0.6452	0.6452	N.A.	0.6519	N.A.	0.6452	0.65	0.65	0.6452

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 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	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
2	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
3	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
4	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
5	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
6	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
7	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
8	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
9	2.862#	14#	2.615#	16#	0.461#	0.042#	2.400#
10	2.649	9	2.402	11	0.247	0.029	2.402
11	2.859#	14#	2.612#	16#	0.461#	0.040#	2.398#
12	1.756	8	1.510	9	0.148	0.020	1.608
13	2.375	24	2.128	25	0.563	0.020	1.812
14	3.122	17	2.875	18	0.520	0.036	2.603
15	4.384	4	4.137	4	0.190	0.065	4.193
16	4.237	1	3.991	1	0.053	0.070	4.185
17	3.502	21	3.255	21	0.724	0.050	2.777
18	3.061	26	2.815	26	0.782	0.048	2.279
19	2.603	10	2.357	10	0.261	0.045	2.343
20	2.527	23	2.280	24	0.571	0.034	1.955
21	2.688	13	2.441	14	0.352	0.044	2.336
22	3.502	9	3.255	10	0.329	0.060	3.173
23	3.369	27	3.122	28	0.901	0.046	2.468
24	1.391	28	1.145	31	0.392	0.017	0.999
25	0.254	1	0.007	7	0.003	0.006	0.251
26	3.437	51	3.191	52	1.738	0.033	1.700
27	3.574	12	3.327	13	0.442	0.054	3.132
28	2.738	4	2.491	4	0.115	0.050	2.623
29	4.089	14	3.843	15	0.593	0.078	3.496
30	3.010	13	2.764	14	0.396	0.046	2.624
31	1.534	22	1.287	23	0.335	0.020	1.199
SUM	88.416	-	80.768	-	14.266	1.287	74.150
AVG	2.852	16	2.605	17	0.460	0.042	2.392
PFRV	0.6452	0.6452	0.6452	0.6452	0.6452	0.6452	0.6452

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 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	3.799#	N	0.659#	48#	160#	3077#	2855#	N
2	O	3.799#	O	0.659#	48#	160#	3077#	2855#	O
3	T	3.799#	T	0.659#	48#	160#	3077#	2855#	T
4		3.799#		0.659#	48#	160#	3077#	2855#	
5	A	3.799#	A	0.659#	48#	160#	3077#	2855#	A
6	P	3.799#	P	0.659#	48#	160#	3077#	2855#	P
7	P	3.799#	P	0.659#	48#	160#	3077#	2855#	P
8	L	3.799#	L	0.659#	48#	160#	3077#	2855#	L
9	I	3.799#	I	0.659#	48#	160#	3077#	2855#	I
10	C	3.202	C	0.353	48	151	927	2827	C
11	A	3.706#	A	0.658#	48#	160#	3077#	2852#	A
12	B	1.924	B	0.212	48	152	1550	1744	B
13	L	1.972	L	0.804	48	150	2910	2492	L
14	E	2.487	E	0.742	48	149	3824	3404	E
15		6.102		0.272	48	154	5037	4652	
16		6.909		0.075	47	143	5771	5004	
17		4.528		1.035	47	165	3683	3329	
18		3.816		1.117	48	162	3237	2961	
19		3.907		0.372	47	159	2691	2521	
20		3.293		0.816	47	160	2628	2424	
21		4.176		0.503	47	160	3134	2600	
22		5.231		0.470	47	156	3903	3577	
23		4.122		1.287	47	163	3587	3244	
24		1.630		0.561	47	164	1293	1173	
25		0.311		0.004	71	162	0	10	
26		3.092		2.482	47	165	3835	3235	
27		5.403		0.631	46	159	4027	3548	
28		4.608		0.164	46	157	3028	2688	
29		5.891		0.847	46	160	4306	4066	
30		4.469		0.566	46	161	3186	2883	
31		1.990		0.478	47	164	1429	1309	
SUM	N.A.	116.960	N.A.	20.380	-	-	94753	88235	N.A.
AVG	N.A.	3.773	N.A.	0.657	47	158	3057	2846	N.A.
PFRV	N.A.	0.6519	N.A.	0.6452	0.6452	0.6452	0.6452	0.6452	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082 DECEMBER 1984

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	675#	N	41#	47#	N	N	N	*	*
2	675#	O	41#	47#	O	O	O	*	*
3	675#	T	41#	47#	T	T	T	*	*
4	675#		41#	47#				*	*
5	675#	A	41#	47#	A	A	A	*	*
6	675#	P	41#	47#	P	P	P	*	*
7	675#	P	41#	47#	P	P	P	*	*
8	675#	L	41#	47#	L	L	L	*	*
9	675#	I	41#	47#	I	I	I	*	*
10	440	C	40	43	C	C	C	9	0
11	675#	A	41#	47#	A	A	A	29	0
12	380	B	41	36	B	B	B	13	0
13	949	L	54	61	L	L	L	0	2
14	265	E	36	36	E	E	E	27	0
15	60		31	31				26	0
16	140		37	40				18	0
17	988		54	60				2	0
18	947		52	65				4	0
19	205		42	41				9	0
20	1039		44	55				11	0
21	319		32	36				24	0
22	471		43	48				11	0
23	1394		42	54				10	0
24	1211		43	56				10	0
25	1379		36	41				30	0
26	1105		31	41				26	0
27	139		21	22				31	0
28	71		32	31				23	0
29	652		70	80				0	12
30	515		51	57				8	0
31	1255		38	49				23	0
SUM	20675	N.A.	-	-	-	-	-	483	18
AVG	667	N.A.	41	47	N.A.	N.A.	N.A.	16	1
PFRV	0.6452	N.A.	0.6452	0.6452	N.A.	N.A.	N.A.	N.A.	N.A.

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MONTHLY REPORT: JANUARY 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3082R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	60.101 MILLION BTU
	23449 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	13.759 MILLION BTU
	5368 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	26 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.25
ECSS OPERATING ENERGY	0.891 MILLION BTU
STORAGE EFFICIENCY	102.03 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.228 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	3.783 MILLION BTU
TOTAL ENERGY CONSUMED	116.800 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	80.739	N.A.	N.A.	80.739 MILLION BTU
SOLAR FRACTION	18	N.A.	N.A.	18 PERCENT
SOLAR ENERGY USED	14.803	N.A.	N.A.	14.803 MILLION BTU
OPERATING ENERGY	0.840	N.A.	N.A.	3.783 MILLION BTU
AUX. THERMAL ENERGY	65.936	N.A.	N.A.	65.936 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	98.495	N.A.	N.A.	98.495 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.891 MILLION BTU
FOSSIL SAVINGS	21.147	N.A.	N.A.	21.147 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.73

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 9.26

* = 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: JANUARY 1985

SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3082R

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	63.406 GIGA JOULES
	266291 KJ/SQ.M.
COLLECTED SOLAR ENERGY	14.516 GIGA JOULES
	60964 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	-3 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.25
ECSS OPERATING ENERGY	0.95 GIGA JOULES
STORAGE EFFICIENCY	102.03 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	1.296 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	3.991 GIGA JOULES
TOTAL ENERGY CONSUMED	123.224 GIGA JOULES

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	85.180	N.A.	N.A.	85.180 GIGA JOULES
SOLAR FRACTION	18	N.A.	N.A.	18 PERCENT
SOLAR ENERGY USED	15.617	N.A.	N.A.	15.617 GIGA JOULES
OPERATING ENERGY	0.826	N.A.	N.A.	3.991 GIGA JOULES
AUX. THERMAL ENG	69.563	N.A.	N.A.	69.563 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	103.913	N.A.	N.A.	103.913 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.95 GIGA JOULES
FOSSIL SAVINGS	22.310	N.A.	N.A.	22.310 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.73

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 9.26

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R 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	0.071	35	0.006	N	0.000	N	0.088
2	0.238	39	0.718	O	0.000	O	3.014
3	1.698	31	0.453	T	0.023	T	0.267
4	1.177	27	0.258		0.014		0.219
5	2.796	32	0.569	A	0.036	A	0.203
6	1.464	35	0.620	P	0.020	P	0.423
7	0.207	26	0.162	P	0.000	P	0.781
8	1.937	22	0.101	L	0.014	L	0.052
9	2.417	15	0.483	I	0.028	I	0.200
10	1.940#	25#	0.482#	C	0.096#	C	0.248#
11	1.923#	25#	0.367#	A	0.096#	A	0.191#
12	2.720	28	0.618	B	0.040	B	0.227
13	3.593	35	1.100	L	0.050	L	0.306
14	1.370	31	0.408	E	0.019	E	0.297
15	1.822	27	0.268		0.025		0.147
16	4.442	17	0.885		0.045		0.199
17	0.485	18	0.328		0.000		0.676
18	2.111	24	0.475		0.033		0.225
19	0.308	30	0.394		0.000		1.280
20	1.058	21	0.160		0.003		0.151
21	3.407	11	0.329		0.039		0.097
22	2.996	23	0.618		0.038		0.206
23	1.525	30	0.484		0.019		0.317
24	1.179	30	0.275		0.019		0.233
25	0.350	27	0.132		0.004		0.378
26	4.099	28	0.580		0.042		0.142
27	1.672	30	0.854		0.022		0.511
28	2.359	24	0.408		0.069		0.173
29	4.020	24	0.440		0.047		0.109
30	3.986	21	1.180		0.049		0.296
31	0.729	18	0.648		0.000		0.888
SUM	60.101	-	14.803	N.A.	0.891	N.A.	-
AVG	1.939	26	0.478	N.A.	0.029	N.A.	0.246
PFRV	0.9073	0.9073	0.9073	N.A.	0.9073	N.A.	0.9073

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R 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	0.071	0.000	0.000	36	0.000	0.000
2	0.238	0.000	0.000	45	0.000	0.000
3	1.698	1.067	0.415	36	0.244	0.389
4	1.177	0.461	0.243	31	0.206	0.526
5	2.796	1.977	0.664	41	0.237	0.336
6	1.464	0.944	0.403	47	0.276	0.428
7	0.207	0.000	0.000	28	0.000	0.000
8	1.937	0.836	0.147	26	0.076	0.176
9	2.417	1.976	0.598	21	0.247	0.302
10	1.940#	1.292#	0.449#	33#	0.231#	0.347#
11	1.923#	1.292#	0.449#	33#	0.233#	0.347#
12	2.720	2.098	0.778	44	0.286	0.371
13	3.593	3.084	1.069	52	0.298	0.347
14	1.370	0.592	0.182	38	0.133	0.307
15	1.822	1.104	0.427	37	0.234	0.387
16	4.442	3.198	1.010	26	0.227	0.316
17	0.485	0.000	0.000	19	0.000	0.000
18	2.111	1.734	0.715	35	0.339	0.412
19	0.308	0.000	0.000	47	0.000	0.000
20	1.058	0.074	0.022	32	0.021	0.292
21	3.407	2.772	0.886	17	0.260	0.320
22	2.996	2.064	0.688	31	0.230	0.333
23	1.525	0.691	0.267	36	0.175	0.387
24	1.179	0.468	0.168	36	0.142	0.359
25	0.350	0.064	0.027	37	0.077	0.420
26	4.099	3.084	0.901	34	0.220	0.292
27	1.672	0.752	0.290	40	0.173	0.386
28	2.359	1.389	0.696	19	0.295	0.501
29	4.020	3.383	1.104	26	0.275	0.326
30	3.986	3.427	1.161	28	0.291	0.339
31	0.729	0.000	0.000	22	0.000	0.000
SUM	60.101	39.822	13.759	-	-	-
AVG	1.939	1.285	0.444	33	0.229	0.346
PFRV	0.9073	0.9073	0.9073	0.9073	0.9073	0.9073

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R 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	0.006	-0.024	79	0.04
2	0.000	0.718	-0.729	67	0.04
3	0.415	0.453	0.012	57	0.20
4	0.243	0.258	-0.031	56	0.06
5	0.664	0.569	0.195	59	0.39
6	0.403	0.620	-0.204	59	0.05
7	0.000	0.162	-0.160	52	0.01
8	0.147	0.101	0.100	51	0.19
9	0.598	0.483	0.400	63	0.63
10	0.449#	0.482#	-0.004	63#	0.08#
11	0.449#	0.367#	-0.018	59#	0.31#
12	0.778	0.618	0.261	58	0.36
13	1.069	1.100	0.056	65	0.31
14	0.182	0.408	-0.191	60	0.13
15	0.427	0.268	0.164	61	0.02
16	1.010	0.885	0.206	69	0.17
17	0.000	0.328	-0.390	63	0.15
18	0.715	0.475	0.236	62	0.01
19	0.000	0.394	-0.398	55	0.02
20	0.022	0.160	-0.127	48	0.04
21	0.886	0.329	0.608	58	0.12
22	0.688	0.618	0.096	69	0.06
23	0.267	0.484	-0.287	66	0.21
24	0.168	0.275	-0.083	58	0.09
25	0.027	0.132	-0.178	53	0.29
26	0.901	0.580	0.378	61	0.18
27	0.290	0.854	-0.291	60	0.97
28	0.696	0.408	0.561	62	0.75
29	1.104	0.440	0.401	74	0.56
30	1.161	1.180	0.132	85	0.25
31	0.000	0.648	-0.833	68	0.39
SUM	13.759	14.803	-0.765	-	-
AVG	0.444	0.478	-0.025	62	0.23
PFRV	0.9073	0.9073	N.A.	0.9073	0.9073

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R JANUARY 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	0.264	2	0.006	0.004	0.258	N	0.319	N	0.008	48	158	19
2	3.637	20	0.718	0.053	2.918	O	4.718	O	1.026	46	162	3508
3	3.457	13	0.453	0.049	3.004	T	4.464	T	0.647	46	157	3450
4	2.411	11	0.257	0.027	2.154		3.204		0.368	46	159	2306
5	3.607	16	0.568	0.024	3.038	A	3.864	A	0.812	46	161	3489
6	2.449	25	0.619	0.062	1.829	P	1.096	P	0.885	46	105	4446
7	2.770	6	0.161	0.048	2.608	P	2.076	P	0.230	45	151	2873
8	1.516	7	0.101	0.051	1.415	L	1.387	L	0.144	45	151	1446
9	0.968	50	0.482	0.049	0.485	I	1.226	I	0.689	43	93	1710
10	2.616#	17#	0.481#	0.026#	2.134#	C	3.109#	C	0.688#	45#	161#	2518#
11	2.238#	16#	0.366#	0.024#	1.872#	A	4.024#	A	0.523#	45#	161#	2114#
12	3.837	16	0.618	0.029	3.219	B	4.619	B	0.883	44	163	3616
13	4.670	24	1.099	0.022	3.570	L	4.851	L	1.571	44	165	4387
14	2.697	15	0.407	0.020	2.290	E	3.510	E	0.582	45	165	2443
15	1.761	15	0.268	0.013	1.493		2.482		0.383	44	167	1485
16	3.098	28	0.885	0.021	2.213		3.546		1.264	44	166	2791
17	1.853	18	0.328	0.014	1.525		2.595		0.468	44	167	1563
18	2.100	23	0.474	0.017	1.625		2.430		0.678	44	167	1808
19	3.588	11	0.394	0.023	3.194		5.007		0.562	44	164	3333
20	4.030	4	0.159	0.031	3.870		4.700		0.228	44	161	3880
21	1.823	18	0.329	0.013	1.494		2.583		0.470	44	167	1534
22	2.286	27	0.617	0.015	1.669		2.654		0.882	43	167	1964
23	2.097	23	0.484	0.016	1.612		3.076		0.691	43	165	1808
24	2.038	13	0.274	0.022	1.763		2.958		0.392	43	162	1808
25	1.594	8	0.132	0.013	1.462		2.489		0.188	42	166	1309
26	3.416	17	0.580	0.030	2.836		4.464		0.829	43	161	3205
27	5.381	15	0.853	0.042	4.527		6.004		1.219	43	161	5263
28	2.140	18	0.407	0.016	1.732		3.770		0.582	44	166	1888
29	1.363	32	0.439	0.014	0.924		2.255		0.628	43	164	1108
30	2.453	48	1.180	0.012	1.273		1.747		1.685	44	167	2160
31	2.564	25	0.647	0.024	1.917		3.252		0.925	44	164	2316
SUM	80.739	-	14.803	0.839	65.936	N.A.	98.495	N.A.	21.147	-	-	77561
AVG	2.604	18	0.477	0.027	2.126	N.A.	3.177	N.A.	0.682	44	158	2501
PFRV	0.9073	0.907	0.9073	0.9073	0.9073	N.A.	0.9099	N.A.	0.9073	0.91	0.91	0.9073

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R JANUARY 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	0.265	2	0.018	19	0.006	0.005	0.258
2	3.637	20	3.390	19	0.718	0.053	2.919
3	3.457	13	3.211	14	0.453	0.049	3.004
4	2.412	11	2.165	11	0.258	0.028	2.154
5	3.607	16	3.360	16	0.569	0.025	3.039
6	2.449	25	2.203	25	0.620	0.062	1.830
7	2.771	6	2.524	6	0.162	0.048	2.609
8	1.516	7	1.269	7	0.101	0.051	1.415
9	0.968	50	0.721	57	0.483	0.049	0.485
10	2.617#	17#	2.370#	19#	0.482#	0.027#	2.135#
11	2.239#	16#	1.992#	18#	0.367#	0.024#	1.872#
12	3.837	16	3.591	17	0.618	0.029	3.219
13	4.671	24	4.424	24	1.100	0.023	3.571
14	2.698	15	2.451	16	0.408	0.021	2.290
15	1.762	15	1.515	16	0.268	0.014	1.493
16	3.099	28	2.852	29	0.885	0.021	2.213
17	1.854	18	1.607	20	0.328	0.015	1.525
18	2.100	23	1.854	24	0.475	0.018	1.626
19	3.588	11	3.341	12	0.394	0.024	3.194
20	4.031	4	3.784	4	0.160	0.032	3.871
21	1.824	18	1.577	18	0.329	0.014	1.494
22	2.287	27	2.040	28	0.618	0.015	1.669
23	2.097	23	1.850	23	0.484	0.016	1.613
24	2.039	13	1.792	14	0.275	0.022	1.764
25	1.595	8	1.348	9	0.132	0.013	1.463
26	3.417	17	3.170	17	0.580	0.031	2.836
27	5.382	15	5.135	16	0.854	0.042	4.528
28	2.140	18	1.893	19	0.408	0.016	1.732
29	1.364	32	1.117	25	0.440	0.015	0.924
30	2.454	48	2.207	43	1.180	0.013	1.274
31	2.565	25	2.318	37	0.648	0.025	1.917
SUM	80.739	-	73.091	-	14.803	0.840	65.936
AVG	2.604	18	2.358	19	0.478	0.027	2.127
PFRV	0.9073	0.9073	0.9073	0.9073	0.9073	0.9073	0.9073

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R JANUARY 1985

HCT 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	0.319	N	0.009	48	158	0	20	N
2	O	4.718	O	1.026	46	162	3706	3509	O
3	T	4.465	T	0.648	46	157	3851	3450	T
4		3.205		0.368	46	159	2565	2306	
5	A	3.865	A	0.812	46	161	3961	3489	A
6	P	1.097	P	0.885	46	105	4783	4447	P
7	P	2.077	P	0.231	45	151	3098	2873	P
8	L	1.388	L	0.144	45	151	1687	1446	L
9	I	1.227	I	0.690	43	93	1973	1710	I
10	C	3.109#	C	0.689#	45#	161#	2882#	2518#	C
11	A	4.025#	A	0.524#	45#	161#	2469#	2114#	A
12	B	4.620	B	0.883	44	163	3983	3616	B
13	L	4.852	L	1.571	44	165	5039	4388	L
14	E	3.511	E	0.582	45	165	2824	2443	E
15		2.482		0.383	44	167	1894	1485	
16		3.547		1.265	44	166	3240	2792	
17		2.596		0.469	44	167	1947	1564	
18		2.430		0.678	44	167	2158	1808	
19		5.008		0.563	44	164	3740	3333	
20		4.701		0.229	44	161	4369	3880	
21		2.584		0.470	44	167	1914	1534	
22		2.655		0.882	43	167	2315	1965	
23		3.076		0.692	43	165	2114	1808	
24		2.958		0.393	43	162	2141	1808	
25		2.489		0.189	42	166	1488	1310	
26		4.464		0.829	43	161	3644	3206	
27		6.004		1.220	43	161	5863	5264	
28		3.771		0.583	44	166	2208	1889	
29		2.255		0.628	43	164	1598	1108	
30		1.748		1.686	44	167	2566	2160	
31		3.252		0.925	44	164	2715	2316	
SUM	N.A.	98.495	N.A.	21.147	-	-	88734	77561	N.A.
AVG	N.A.	3.177	N.A.	0.682	44	158	2362	2502	N.A.
PFRV	N.A.	0.9099	N.A.	0.9073	0.9073	0.9073	0.9073	0.9073	N.A.

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3082R 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	28	N	35	36	N	N	N	31	0
2	93	O	39	45	O	O	O	12	0
3	662	T	31	36	T	T	T	28	0
4	459		27	31				38	0
5	1091	A	32	41	A	A	A	30	0
6	571	P	35	47	P	P	P	19	0
7	81	P	26	28	P	P	P	32	0
8	756	L	22	26	L	L	L	43	0
9	943	I	15	21	I	I	I	44	0
10	757#	C	25#	33#	C	C	C	55	0
11	750#	A	25#	33#	A	A	A	37	0
12	1061	B	28	44	B	B	B	26	0
13	1402	L	35	52	L	L	L	20	0
14	535	E	31	38	E	E	E	25	0
15	711		27	37				32	0
16	1733		17	26				41	0
17	189		18	19				34	0
18	824		24	35				39	0
19	120		30	47				25	0
20	413		21	32				35	0
21	1329		11	17				48	0
22	1169		23	31				40	0
23	595		30	36				29	0
24	460		30	36				31	0
25	136		27	37				31	0
26	1599		28	34				28	0
27	652		30	40				26	0
28	921		24	19				14	0
29	1568		24	26				42	0
30	1555		21	28				44	0
31	285		18	22				49	0
SUM	23449	N.A.	-	-	-	-	-	1029	0
AVG	756	N.A.	26	33	N.A.	N.A.	N.A.	33	0
PFRV	0.9073	N.A.	0.9073	0.9073	N.A.	N.A.	N.A.	N.A.	N.A.

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MONTHLY REPORT: FEBRUARY 1985

SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3108

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	83.840 MILLION BTU
	32712 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	24.490 MILLION BTU
	9555 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	31 DEGREES F
AVERAGE BUILDING TEMPERATURE	56 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.29
ECSS OPERATING ENERGY	0.998 MILLION BTU
STORAGE EFFICIENCY	102.95 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.568 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	1.959 MILLION BTU
TOTAL ENERGY CONSUMED	106.495 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	80.573	N.A.	N.A.	80.573 MILLION BTU
SOLAR FRACTION	30	N.A.	N.A.	30 PERCENT
SOLAR ENERGY USED	24.197	N.A.	N.A.	24.197 MILLION BTU
OPERATING ENERGY	0.961	N.A.	N.A.	1.959 MILLION BTU
AUX. THERMAL ENERGY	12.137	N.A.	N.A.	12.137 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	80.046	N.A.	N.A.	80.046 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.998 MILLION BTU
FOSSIL SAVINGS	34.567	N.A.	N.A.	34.567 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.93

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.30

* = 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: FEBRUARY 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3108

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	88.451 GIGA JOULES
	371475 KJ/SQ.M.
COLLECTED SOLAR ENERGY	25.837 GIGA JOULES
	108510 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	-1 DEGREES C
AVERAGE BUILDING TEMPERATURE	14 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.29
ECSS OPERATING ENERGY	1.053 GIGA JOULES
STORAGE EFFICIENCY	102.95 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.226 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.067 GIGA JOULES
TOTAL ENERGY CONSUMED	112.352 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	85.004	N.A.	N.A.	85.004 GIGA JOULES
SOLAR FRACTION	30	N.A.	N.A.	30 PERCENT
SOLAR ENERGY USED	25.528	N.A.	N.A.	25.528 GIGA JOULES
OPERATING ENERGY	1.014	N.A.	N.A.	2.067 GIGA JOULES
AUX. THERMAL ENG	12.804	N.A.	N.A.	12.804 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	84.448	N.A.	N.A.	84.448 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.053 GIGA JOULES
FOSSIL SAVINGS	36.468	N.A.	N.A.	36.468 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.93

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.30

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	0.314	29	0.112	N	0.000	N	0.357
2	0.400	29	0.131	O	0.001	O	0.328
3	2.344	20	0.391	T	0.034	T	0.167
4	4.418	16	0.586		0.050		0.133
5	1.532	16	0.644	A	0.017	A	0.420
6	1.773	16	0.187	P	0.002	P	0.106
7	4.172	19	0.409	P	0.038	P	0.098
8	3.420	10	0.608	L	0.035	L	0.178
9	4.009	17	1.159	I	0.044	I	0.289
10	4.607	29	1.717	C	0.056	C	0.373
11	4.435	30	1.001	A	0.053	A	0.226
12	0.483	35	0.684	B	0.000	B	1.416
13	0.892	39	0.264	L	0.016	L	0.296
14	3.952	32	0.764	E	0.056	E	0.193
15	1.071	31	0.642		0.007		0.599
16	3.882	27	0.923		0.057		0.238
17	4.362	34	1.530		0.055		0.351
18	3.864	34	1.264		0.048		0.327
19	3.500	37	1.337		0.042		0.382
20	4.072	32	1.386		0.049		0.340
21	4.165	34	1.294		0.055		0.311
22	1.667	45	0.627		0.022		0.376
23	0.601	48	0.403		0.012		0.670
24	3.710	57	1.102		0.063		0.297
25	4.648	45	1.795		0.048		0.386
26	4.160	40	1.325		0.047		0.318
27	2.006	41	0.795		0.030		0.396
28	5.380	28	1.118		0.061		0.208
SUM	83.840	-	24.197	N.A.	0.998	N.A.	-
AVG	2.994	31	0.864	N.A.	0.036	N.A.	0.289
PFRV	0.9970	0.9970	0.9970	N.A.	0.9970	N.A.	0.9970

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	0.314	0.000	0.000	31	0.000	0.000
2	0.400	0.006	0.006	32	0.016	0.981
3	2.344	1.585	0.510	23	0.217	0.322
4	4.418	3.739	1.207	25	0.273	0.323
5	1.532	0.548	0.194	24	0.126	0.353
6	1.773	0.139	0.047	16	0.027	0.339
7	4.172	3.149	0.715	23	0.171	0.227
8	3.420	2.187	0.710	13	0.207	0.324
9	4.009	3.071	1.142	22	0.285	0.372
10	4.607	4.071	1.589	37	0.345	0.390
11	4.435	3.835	1.453	38	0.328	0.379
12	0.483	0.000	0.000	37	0.000	0.000
13	0.892	0.533	0.250	41	0.281	0.470
14	3.952	3.520	1.305	38	0.330	0.371
15	1.071	0.141	0.104	36	0.097	0.742
16	3.882	3.425	1.263	32	0.325	0.369
17	4.362	3.887	1.507	42	0.345	0.388
18	3.864	2.934	1.110	39	0.287	0.378
19	3.500	2.917	1.173	45	0.335	0.402
20	4.072	3.427	1.347	36	0.331	0.393
21	4.165	3.540	1.356	40	0.326	0.383
22	1.667	0.881	0.436	49	0.262	0.495
23	0.601	0.142	0.082	52	0.136	0.576
24	3.710	3.469	1.616	66	0.436	0.466
25	4.648	3.860	1.567	46	0.337	0.406
26	4.160	3.585	1.500	47	0.360	0.418
27	2.006	1.233	0.551	49	0.275	0.447
28	5.380	4.797	1.751	32	0.325	0.365
SUM	83.340	64.625	24.490	-	-	-
AVG	2.994	2.308	0.875	36	0.292	0.379
PFRV	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	0.112	-0.129	53	0.82
2	0.006	0.131	-0.116	48	0.18
3	0.510	0.391	0.146	50	0.79
4	1.207	0.586	0.668	66	0.41
5	0.194	0.644	-0.513	66	0.49
6	0.047	0.187	-0.175	54	1.43
7	0.715	0.409	0.320	53	0.27
8	0.710	0.608	0.162	66	0.44
9	1.142	1.159	0.069	71	0.49
10	1.589	1.717	-0.027	74	0.58
11	1.453	1.001	0.540	81	0.40
12	0.000	0.684	-0.804	75	0.65
13	0.250	0.264	-0.005	60	0.29
14	1.305	0.764	0.617	73	0.54
15	0.104	0.642	-0.611	69	0.56
16	1.263	0.923	0.376	67	0.31
17	1.507	1.530	0.096	76	0.64
18	1.110	1.264	-0.076	76	0.43
19	1.173	1.337	-0.117	75	0.29
20	1.347	1.386	0.019	75	0.35
21	1.356	1.294	-0.004	78	0.36
22	0.436	0.627	-0.203	66	0.16
23	0.082	0.403	-0.302	57	0.46
24	1.616	1.102	0.664	67	1.63
25	1.567	1.795	-0.098	81	0.74
26	1.500	1.325	0.299	81	0.64
27	0.551	0.795	-0.423	74	1.40
28	1.751	1.118	0.670	82	0.17
SUM	24.490	24.197	1.015	-	-
AVG	0.875	0.864	0.036	68	0.57
PFRV	0.9970	0.9970	N.A.	0.9970	0.9970

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	1.694	7	0.112	0.023	2.094	N	2.991	N	0.160	44	167	1417
2	3.019	4	0.131	0.035	2.869	O	4.097	O	0.187	44	159	2873
3	4.659	8	0.391	0.060	0.658	T	0.940	T	0.558	44	149	5052
4	1.661	35	0.585	0.045	0.588		0.840		0.837	45	136	1847
5	1.934	33	0.644	0.056	0.069	A	0.098	A	0.920	44	117	2775
6	2.012	9	0.187	0.067	1.572	P	2.245	P	0.267	44	145	2101
7	2.467	17	0.409	0.028	2.360	P	3.371	P	0.584	44	163	2248
8	2.496	24	0.607	0.031	1.954	L	2.791	L	0.868	44	159	2345
9	3.563	33	1.158	0.029	2.394	I	3.419	I	1.655	44	161	3401
10	4.215	41	1.716	0.037	2.770	C	3.956	C	2.452	45	163	4036
11	2.119	47	1.001	0.032	1.453	A	2.075	A	1.430	44	156	2003
12	2.239	31	0.683	0.018	1.714	B	2.448	B	0.976	46	163	2042
13	1.910	14	0.263	0.029	1.637	L	2.338	L	0.376	47	164	1700
14	2.355	32	0.764	0.026	1.717	E	2.453	E	1.091	46	162	2169
15	2.457	26	0.642	0.031	2.177		3.110		0.917	45	161	2286
16	3.501	26	0.922	0.036	2.729		3.898		1.318	45	160	3371
17	3.912	39	1.530	0.032	2.717		3.880		2.185	45	162	3738
18	3.506	36	1.263	0.026	2.338		3.339		1.805	44	163	3303
19	3.309	40	1.337	0.033	2.303		3.290		1.910	44	164	3068
20	3.553	39	1.385	0.038	2.450		3.500		1.979	44	163	3342
21	2.836	46	1.293	0.035	1.923		2.747		1.848	45	161	2678
22	2.649	24	0.627	0.038	2.339		3.341		0.896	45	159	2531
23	3.784	11	0.402	0.045	3.623		5.175		0.575	45	161	3664
24	3.753	29	1.101	0.031	2.760		3.943		1.573	45	157	3772
25	3.558	50	1.794	0.015	1.831		2.615		2.563	47	166	3332
26	2.706	49	1.324	0.022	1.606		2.294		1.892	45	164	2472
27	2.424	33	0.795	0.022	1.967		2.809		1.135	45	165	2179
28	2.268	49	1.118	0.028	1.420		2.028		1.597	44	161	2081
SUM	80.572	-	24.197	0.961	56.032	N.A.	80.045	N.A.	34.567	-	-	77840
AVG	2.877	30	0.864	0.034	2.001	N.A.	2.858	N.A.	1.234	45	158	2780
PFRV	0.9970	0.997	0.9970	0.9970	0.9970	N.A.	0.9970	N.A.	0.9970	1.00	1.00	0.9970

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	1.694	7	1.447	I	0.112	0.023	2.094
2	3.019	4	2.773		0.131	0.036	2.869
3	4.660	8	4.413		0.391	0.060	0.658
4	1.661	35	1.414		0.586	0.046	0.588
5	1.935	33	1.688		0.644	0.056	0.069
6	2.013	9	1.766		0.187	0.067	1.572
7	2.467	17	2.221		0.409	0.029	2.360
8	2.497	24	2.250		0.608	0.031	1.954
9	3.563	33	3.317		1.159	0.029	2.394
10	4.215	41	3.969		1.717	0.037	2.770
11	2.119	47	1.873		1.001	0.032	1.453
12	2.239	31	1.993		0.684	0.019	1.714
13	1.911	14	1.664		0.264	0.030	1.637
14	2.356	32	2.109		0.764	0.027	1.717
15	2.458	26	2.211		0.642	0.032	2.177
16	3.502	26	3.255		0.923	0.036	2.729
17	3.912	39	3.665		1.530	0.033	2.717
18	3.507	36	3.260		1.264	0.026	2.338
19	3.309	40	3.062		1.337	0.034	2.303
20	3.554	39	3.307		1.386	0.038	2.450
21	2.836	46	2.589		1.294	0.035	1.923
22	2.649	24	2.402		0.627	0.039	2.339
23	3.784	11	3.538		0.403	0.046	3.623
24	3.754	29	3.507		1.102	0.031	2.760
25	3.559	50	3.312		1.795	0.015	1.831
26	2.706	49	2.459		1.325	0.022	1.606
27	2.425	33	2.178		0.795	0.023	1.967
28	2.268	49	2.022	I	1.118	0.028	1.420
SUM	80.573	-	73.664	-	24.197	0.961	56.032
AVG	2.878	30	2.631	33	0.864	0.034	2.001
PFRV	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	2.992	N	0.161	44	167	1671	1417	N
2	O	4.098	O	0.188	44	159	3156	2874	O
3	T	0.940	T	0.559	44	149	5839	5053	T
4		0.840		0.837	45	136	2325	1847	
5	A	0.099	A	0.920	44	117	3224	2776	A
6	P	2.245	P	0.268	44	145	2411	2101	P
7	P	3.372	P	0.585	44	163	2501	2248	P
8	L	2.792	L	0.868	44	159	2613	2346	L
9	I	3.420	I	1.655	44	161	3580	3401	I
10	C	3.957	C	2.452	45	163	4459	4037	C
11	A	2.075	A	1.430	44	156	2210	2004	A
12	B	2.448	B	0.977	46	163	2270	2043	B
13	L	2.338	L	0.377	47	164	1996	1700	L
14	E	2.453	E	1.092	46	162	2531	2169	E
15		3.110		0.917	45	161	2471	2287	
16		3.899		1.318	45	160	3960	3371	
17		3.881		2.186	45	162	3978	3739	
18		3.340		1.805	44	163	3669	3303	
19		3.290		1.910	44	164	3319	3069	
20		3.501		1.979	44	163	3635	3342	
21		2.747		1.848	45	161	3090	2678	
22		3.342		0.896	45	159	2798	2532	
23		5.175		0.575	45	161	4056	3665	
24		3.943		1.574	45	157	4176	3772	
25		2.616		2.564	47	166	3744	3333	
26		2.295		1.892	45	164	2871	2473	
27		2.810		1.136	45	165	2477	2180	
28		2.029		1.598	44	161	2303	2082	
SUM	N.A.	80.046	N.A.	34.567	-	-	87332	77840	N.A.
AVG	N.A.	2.859	N.A.	1.235	45	158	3119	2780	N.A.
PFRV	N.A.	0.9970	N.A.	0.9970	0.9970	0.9970	0.9970	0.9970	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3108 FEBRUARY 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	123	N	29	31	N	N	N	37	0
2	156	O	29	32	O	O	O	37	0
3	914	T	20	23	T	T	T	46	0
4	1724		16	25				50	0
5	598	A	16	24	A	A	A	49	0
6	692	P	16	16	P	P	P	49	0
7	1628	P	19	23	P	P	P	46	0
8	1334	L	10	13	L	L	L	52	0
9	1564	I	17	22	I	I	I	48	0
10	1798	C	29	37	C	C	C	37	0
11	1730	A	30	38	A	A	A	37	0
12	188	B	35	37	B	B	B	30	0
13	348	L	39	41	L	L	L	27	0
14	1542	E	32	38	E	E	E	32	0
15	418		31	36				33	0
16	1515		27	32				39	0
17	1702		34	42				32	0
18	1508		34	39				31	0
19	1366		37	45				27	0
20	1589		32	36				33	0
21	1625		34	40				33	0
22	650		45	49				20	0
23	234		48	52				17	0
24	1447		57	66				10	0
25	1813		45	46				19	0
26	1623		40	47				24	0
27	783		41	49				27	0
28	2099		28	32				38	0
SUM	32712	N.A.	-	-	-	-	-	960	0
AVG	1168	N.A.	31	36	N.A.	N.A.	N.A.	34	0
PFRV	0.9970	N.A.	0.9970	0.9970	N.A.	N.A.	N.A.	N.A.	N.A.

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MONTHLY REPORT: MARCH 1981

SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3115

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	123.897 MILLION BTU
	48341 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	40.284 MILLION BTU
	15718 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	40 DEGREES F
AVERAGE BUILDING TEMPERATURE	58 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	1.033 MILLION BTU
STORAGE EFFICIENCY	96.2 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.252 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.557 MILLION BTU
TOTAL ENERGY CONSUMED	121.907 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	92.601	N.A.	N.A.	92.601 MILLION BTU
SOLAR FRACTION	42	N.A.	N.A.	42 PERCENT
SOLAR ENERGY USED	44.548	N.A.	N.A.	39.010 MILLION BTU
OPERATING ENERGY	1.006	N.A.	N.A.	2.557 MILLION BTU
AUX. THERMAL ENERGY	56.238	N.A.	N.A.	56.238 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	80.340	N.A.	N.A.	80.340 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.033 MILLION BTU
FOSSIL SAVINGS	63.640	N.A.	N.A.	63.640 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.04

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 35.42

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: MARCH 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3115

	SI UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	130.712 GIGA JOULES
	548958 KJ/SQ.M.
COLLECTED SOLAR ENERGY	42.500 GIGA JOULES
	178489 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	4 DEGREES C
AVERAGE BUILDING TEMPERATURE	15 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	1.090 GIGA JOULES
STORAGE EFFICIENCY	96.2 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	1.434 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.697 GIGA JOULES
TOTAL ENERGY CONSUMED	128.612 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	97.694	N.A.	N.A.	97.694 GIGA JOULES
SOLAR FRACTION	42	N.A.	N.A.	42 PERCENT
SOLAR ENERGY USED	46.998	N.A.	N.A.	41.156 GIGA JOULES
OPERATING ENERGY	1.062	N.A.	N.A.	2.697 GIGA JOULES
AUX. THERMAL ENG	59.331	N.A.	N.A.	59.331 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	84.759	N.A.	N.A.	84.759 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.090 GIGA JOULES
FOSSIL SAVINGS	67.140	N.A.	N.A.	67.140 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.04
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 35.42

* = 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: LAUNDERETTE, FORT DEVENS - P-3115 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	4.706	43	1.840	N	0.051	N	0.391
2	3.949	44	1.934	O	0.052	O	0.490
3	5.327	33	2.160	T	0.061	T	0.406
4	1.296	20	0.461		0.012		0.355
5	1.409	30	0.233	A	0.008	A	0.165
6	5.538	26	1.278	P	0.053	P	0.231
7	3.930	28	1.119	P	0.054	P	0.285
8	3.686#	40#	0.989#	L	0.032#	L	0.391#
9	3.999#	40#	0.989#	I	0.033#	I	0.362#
10	3.999#	40#	0.989#	C	0.033#	C	0.362#
11	4.127	47	0.989#	A	0.010	A	0.251#
12	0.349	46	0.989#	B	0.000	B	4.147#
13	1.401	46	0.989#	L	0.000	L	1.033#
14	3.537	46	0.989#	E	0.000	E	0.409#
15	4.000	40	0.989#		0.000		0.362#
16	5.860	38	0.989#		0.002		0.247#
17	2.257	44	0.989#		0.000		0.641#
18	1.726	34	0.989#		0.000		0.839#
19	5.956	37	1.108		0.006		0.186
20	5.217	46	2.254		0.057		0.432
21	6.055	33	1.567		0.058		0.259
22	5.840	36	1.174		0.060		0.201
23	2.701	43	1.604		0.058		0.594
24	3.425	41	1.640		0.057		0.479
25	6.120	33	1.711		0.056		0.280
26	6.036	38	1.443		0.061		0.239
27	4.427	53	1.422		0.053		0.321
28	4.511	65	1.772		0.055		0.393
29	4.516	49	1.428		0.045		0.316
30	3.999#	40#	0.989#		0.033#		0.362#
31	3.999#	40#	0.989#		0.033#		0.362#
SUM	123.897	-	39.010	N.A.	1.033	N.A.	-
AVG	3.997	40	1.258	N.A.	0.033	N.A.	0.360
PFRV	0.8145	0.8145	0.5524	N.A.	0.8132	N.A.	0.5524

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - F-3115 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	4.706	4.150	1.614	53	0.343	0.389
2	3.949	3.551	1.516	54	0.384	0.427
3	5.327	4.866	1.879	37	0.353	0.386
4	1.296	0.473	0.232	22	0.179	0.492
5	1.409	0.282	0.089	32	0.063	0.316
6	5.538	4.722	1.860	26	0.336	0.394
7	3.930	3.272	1.244	37	0.317	0.380
8	3.686#	3.194#	1.261#	45#	0.342#	0.395#
9	3.999#	3.294#	1.296#	45#	0.324#	0.394#
10	3.999#	3.294#	1.296#	45#	0.324#	0.394#
11	4.127	3.602	1.576	58	0.382	0.438
12	0.349	0.000	0.000	51	0.000	0.000
13	1.401	0.637	0.238	50	0.170	0.374
14	3.537	2.716	1.185	49	0.335	0.436
15	4.000	3.051	1.179	46	0.295	0.386
16	5.860	5.235	2.117	41	0.361	0.404
17	2.257	1.745	0.741	53	0.328	0.425
18	1.726	0.281	0.112	35	0.065	0.398
19	5.956	5.539	2.234	44	0.375	0.403
20	5.217	4.714	1.836	55	0.352	0.389
21	6.055	5.156	1.988	37	0.328	0.386
22	5.840	5.128	1.818	42	0.311	0.354
23	2.701	2.122	0.810	53	0.300	0.382
24	3.425	2.942	1.208	48	0.353	0.411
25	6.120	5.022	1.929	38	0.315	0.384
26	6.036	5.254	1.842	44	0.305	0.351
27	4.427	3.679	1.541	61	0.348	0.419
28	4.511	3.833	1.555	73	0.345	0.406
29	4.516	3.879	1.493	37	0.331	0.385
30	3.999#	3.294#	1.296#	45#	0.324#	0.394#
31	3.999#	3.294#	1.296#	45#	0.324#	0.394#
SUM	123.897	102.218	40.284	-	-	-
AVG	3.997	3.297	1.299	45	0.325	0.394
PFRV	0.8145	0.8145	0.8145	0.8145	0.8145	0.8145

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3115 MARCH 85

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	1.614	1.840	-0.067	95	0.50
2	1.516	1.934	-0.431	81	0.07
3	1.879	2.160	-0.108	77	1.09
4	0.232	0.461	-0.316	63	1.07
5	0.089	0.233	-0.144	55	0.02
6	1.860	1.278	0.733	73	0.91
7	1.244	1.119	0.062	81	0.29
8	1.261#	0.989#	-0.019	81#	0.78#
9	1.296#	0.989#	*	79#	*
10	1.296#	0.989#	*	79#	*
11	1.576	0.989#	-0.518	83	*
12	0.000	0.989#	-0.489	65	*
13	0.238	0.989#	-0.059	57	*
14	1.185	0.989#	0.591	70	*
15	1.179	0.989#	-0.298	75	0.18
16	2.117	0.989#	0.550	78	0.58
17	0.741	0.989#	-0.675	72	0.22
18	0.112	0.989#	-0.181	57	*
19	2.234	1.108	0.912	78	0.95
20	1.836	2.254	-0.273	90	0.50
21	1.988	1.567	0.458	88	0.12
22	1.818	1.174	0.286	102	0.85
23	0.810	1.604	-0.687	87	0.40
24	1.208	1.640	-0.260	74	1.15
25	1.929	1.711	0.507	84	1.12
26	1.842	1.443	0.354	96	0.13
27	1.541	1.422	-0.109	99	0.66
28	1.555	1.772	-0.025	99	0.66
29	1.493	1.428	0.160	86	0.43
30	1.296#	0.989#	*	79#	*
31	1.296#	0.989#	*	79#	*
SUM	40.284	39.010	-0.41	-	-
AVG	1.299	1.258	0.013	79	0.145
PFRV	0.8145	0.5524	N.A.	0.8145	0.8145

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3115 MARCH 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	2.873	64	1.839	0.023	1.191	N	1.702	N	2.628	45	164	2638
2	4.462	43	1.934	0.031	2.764	O	3.949	O	2.763	45	160	4388
3	5.301	41	2.160	0.031	2.882	T	4.118	T	3.086	45	163	5160
4	2.550	18	0.460	0.035	2.493		3.561		0.658	46	162	2374
5	2.724	9	0.233	0.031	2.653	A	3.790	A	0.333	45	160	2580
6	2.655	48	1.278	0.020	1.429	P	2.041	P	1.826	46	165	2430
7	2.789	40	1.118	0.030	2.005	P	2.865	P	1.597	46	162	2628
8	3.001#	47#	0.989#	0.030#	1.729#	L	2.470#	L	2.058#	46#	163#	2825#
9	3.010#	47#	0.989#	0.032#	1.814#	I	2.592#	I	2.068#	46#	163#	2835#
10	3.010#	47#	0.989#	0.032#	1.814#	C	2.592#	C	2.068#	46#	163#	2835#
11	2.117#	47#	0.989#	0.025#	2.045#	A	2.921#	A	1.477#	46#	163#	1910#
12	3.010#	47#	0.989#	0.032#	1.814#	B	2.592#	B	2.068#	46#	163#	2835#
13	3.010#	47#	0.989#	0.032#	1.814#	L	2.592#	L	2.068#	46#	163#	2835#
14	3.010#	47#	0.989#	0.032#	1.814#	E	2.592#	E	2.068#	46#	163#	2835#
15	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
16	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
17	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
18	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
19	2.300	47	1.107	0.025	1.480		2.114		1.582	45	163	2100
20	3.534	64	2.253	0.025	1.257		1.796		3.219	45	163	3323
21	2.770	57	1.567	0.038	1.488		2.126		2.238	45	161	2609
22	1.535	77	1.174	0.063	0.896		1.280		1.677	45	155	1407
23	3.012	53	1.603	0.064	1.841		2.630		2.291	46	163	2814
24	4.906	33	1.640	0.052	3.610		5.157		2.342	45	160	4847
25	3.062	56	1.711	0.037	1.598		2.283		2.444	45	163	2863
26	2.115	68	1.442	0.028	0.941		1.344		2.061	45	161	1944
27	2.220	64	1.422	0.012	1.020		1.458		2.031	46	166	1974
28	2.670	66	1.772	0.009	0.987		1.410		2.531	47	166	2443
29	2.878	49	1.427	0.029	1.957		2.797		2.039	46	163	2692
30	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
31	3.010#	47#	0.989#	0.032#	1.814#		2.592#		2.068#	46#	163#	2835#
SUM	92.600	-	39.010	1.006	56.238	N.A.	80.340	N.A.	63.640	-	-	87146
AVG	2.987	47	1.258	0.032	1.814	N.A.	2.591	N.A.	2.052	45	162	2811
PFRV	0.5524	0.552	0.5524	0.5511	0.5524	N.A.	0.5524	N.A.	0.5524	0.55	0.55	0.5524

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3115 MARC 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	2.873	64	2.627	I	1.840	0.023	1.192
2	4.462	43	4.216		1.934	0.032	2.765
3	5.301	41	5.055		2.160	0.032	2.883
4	2.550	18	2.304		0.461	0.035	2.493
5	2.724	9	2.477		0.233	0.031	2.653
6	2.655	48	2.408		1.278	0.021	1.429
7	2.789	40	2.543		1.119	0.030	2.006
8	3.002#	47#	2.755#		0.989#	0.031#	1.730#
9	3.011#	47#	2.764#		0.989#	0.033#	1.815#
10	3.011#	47#	2.764#		0.989#	0.033#	1.815#
11	2.118#	47#	1.871#		0.989#	0.026#	2.045#
12	3.011#	47#	2.764#		0.989#	0.033#	1.815#
13	3.011#	47#	2.764#		0.989#	0.033#	1.815#
14	3.011#	47#	2.764#		0.989#	0.033#	1.815#
15	3.011#	47#	2.764#		0.989#	0.033#	1.815#
16	3.011#	47#	2.764#		0.989#	0.033#	1.815#
17	3.011#	47#	2.764#		0.989#	0.033#	1.815#
18	3.011#	47#	2.764#		0.989#	0.033#	1.815#
19	2.300	47	2.054		1.108	0.026	1.480
20	3.534	64	3.287		2.254	0.026	1.258
21	2.771	57	2.524		1.567	0.039	1.488
22	1.535	77	1.288		1.174	0.063	0.896
23	3.013	53	2.766		1.604	0.064	1.842
24	4.907	33	4.660		1.640	0.052	3.611
25	3.063	56	2.816		1.711	0.037	1.598
26	2.116	68	1.869		1.443	0.029	0.941
27	2.221	64	1.974		1.422	0.013	1.021
28	2.671	66	2.424		1.772	0.009	0.987
29	2.878	49	2.632		1.428	0.029	1.958
30	3.011#	47#	2.764#		0.989#	0.033#	1.815#
31	3.011#	47#	2.764#	I	0.989#	0.033#	1.815#
SUM	92.601	-	84.952	-	39.010	1.006	56.238
AVG	2.987	47	2.740	I	1.258	0.032	1.814
PFRV	0.5524	0.5524	0.5524	0.5511	0.5524	0.5511	0.5524

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3115 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	1.702	N	2.628	45	164	3026	2639	N
2	O	3.950	O	2.763	45	160	4902	4388	O
3	T	4.118	T	3.086	45	163	5775	5161	T
4		3.562		0.658	46	162	2601	2375	
5	A	3.790	A	0.333	45	160	2826	2580	A
6	P	2.042	P	1.826	46	165	2598	2430	P
7	P	2.865	P	1.598	46	162	2970	2629	P
8	L	2.471#	L	2.058#	46#	163#	3164#	2825#	L
9	I	2.593#	I	2.068#	46#	163#	3171#	2835#	I
10	C	2.593#	C	2.068#	46#	163#	3171#	2835#	C
11	A	2.921#	A	1.477#	46#	163#	2125#	1910#	A
12	B	2.593#	B	2.068#	46#	163#	3171#	2835#	B
13	L	2.593#	L	2.068#	46#	163#	3171#	2835#	L
14	E	2.593#	E	2.068#	46#	163#	3171#	2835#	E
15		2.593#		2.068#	46#	163#	3171#	2835#	
16		2.593#		2.068#	46#	163#	3171#	2835#	
17		2.593#		2.068#	46#	163#	3171#	2835#	
18		2.593#		2.068#	46#	163#	3171#	2835#	
19		2.115		1.582	45	163	2764	2101	
20		1.797		3.220	45	163	3617	3323	
21		2.126		2.239	45	161	2890	2610	
22		1.280		1.678	45	155	1607	1407	
23		2.631		2.291	46	163	3062	2815	
24		5.158		2.343	45	160	5167	4847	
25		2.283		2.445	45	163	3099	2864	
26		1.344		2.061	45	161	2161	1945	
27		1.458		2.032	46	166	2347	1974	
28		1.410		2.532	47	166	2905	2443	
29		2.797		2.040	46	163	2885	2692	
30		2.593#		2.068#	46#	163#	3171#	2835#	
31		2.593#		2.068#	46#	163#	3171#	2835#	
SUM	N.A.	80.340	N.A.	63.640	-	-	97371	87146	N.A.
AVG	N.A.	2.592	N.A.	2.053	45	162	3141	2811	N.A.
PFRV	N.A.	0.5524	N.A.	0.5524	0.5524	0.5524	0.5524	0.5524	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3115 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	1836	N	43	53	N	N	N	23	0
2	1541	O	44	54	O	O	O	19	0
3	2079	T	33	37	T	T	T	32	0
4	506		20	22				44	0
5	550	A	30	32	A	A	A	34	0
6	2161	P	26	26	P	P	P	40	0
7	1533	P	28	37	P	P	P	40	0
8	1438#	L	40#	45#	L	L	L	31	0
9	1560#	I	40#	45#	I	I	I	*	*
10	1560#	C	40#	45#	C	C	C	*	*
11	1610	A	47	58	A	A	A	12	0
12	136	B	46	51	B	B	B	18	0
13	547	L	46	50	L	L	L	19	0
14	1380	E	46	49	E	E	E	18	0
15	1561		40	46				23	0
16	2286		38	41				27	0
17	881		44	53				19	0
18	673		34	35				31	0
19	2324		37	44				27	0
20	2035		46	55				18	0
21	2363		33	37				33	0
22	2279		36	42				29	0
23	1054		43	53				22	0
24	1336		41	48				22	0
25	2388		33	38				32	0
26	2355		38	44				29	0
27	1727		53	61				15	0
28	1760		65	73				1	0
29	1762		49	37				9	0
30	1560#		40#	45#				*	*
31	1560#		40#	45#				*	*
SUM	48341	N.A.	-	-	-	-	-	765	0
AVG	1559	N.A.	40	45	N.A.	N.A.	N.A.	25	0
PFRV	0.8145	N.A.	0.8145	0.8145	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 REPORT: APRIL 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	119.186 MILLION BTU 46503 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	40.060 MILLION BTU @ 15630 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	50 DEGREES F
AVERAGE BUILDING TEMPERATURE	63 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.34
ECSS OPERATING ENERGY	1.460 MILLION BTU
STORAGE EFFICIENCY	104.99 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.657 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	2.357 MILLION BTU
TOTAL ENERGY CONSUMED	100.964 MILLION BTU

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	86.991	N.A.	N.A.	86.991 MILLION BTU
SOLAR FRACTION	47	N.A.	N.A.	47 PERCENT
SOLAR ENERGY USED	40.863	N.A.	N.A.	40.863 MILLION BTU
OPERATING ENERGY	0.897	N.A.	N.A.	2.357 MILLION BTU
AUX. THERMAL ENERGY	40.031	N.A.	N.A.	40.031 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	57.187	N.A.	N.A.	57.187 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.460 MILLION BTU
FOSSIL SAVINGS	58.376	N.A.	N.A.	58.376 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.34
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 11.52

* = 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: APRIL 1985

SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	125.741 GIGA JOULES
	528084 KJ/SQ.M.
COLLECTED SOLAR ENERGY	42.263 GIGA JOULES @
	177495 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	10 DEGREES C
AVERAGE BUILDING TEMPERATURE	17 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.34
ECSS OPERATING ENERGY	1.540 GIGA JOULES
STORAGE EFFICIENCY	104.99 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	3.733 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	2.486 GIGA JOULES
TOTAL ENERGY CONSUMED	106.517 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	91.776	N.A.	N.A.	91.776 GIGA JOULES
SOLAR FRACTION	47	N.A.	N.A.	47 PERCENT
SOLAR ENERGY USED	43.111	N.A.	N.A.	43.111 GIGA JOULES
OPERATING ENERGY	0.946	N.A.	N.A.	2.486 GIGA JOULES
AUX. THERMAL ENG	42.232	N.A.	N.A.	42.232 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	60.332	N.A.	N.A.	60.332 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.540 GIGA JOULES
FOSSIL SAVINGS	61.587	N.A.	N.A.	61.587 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.34

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 11.52

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

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

@ = SEE APRIL PERFORMANCE REPORT.

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	1.363	39	0.301	N	0.009	N	0.221
2	2.919	40	0.726	O	0.047	O	0.249
3	3.267	41	0.867	T	0.042	T	0.266
4	4.281	46	0.994		0.055		0.232
5	2.964	45	1.130	A	0.044	A	0.381
6	1.565	53	0.914	P	0.038	P	0.584
7	5.621	51	0.018	P	0.073	P	0.003
8	5.020	41	2.865	L	0.040	L	0.571
9	6.012	37	1.919	I	0.062	I	0.319
10	4.314#	44#	1.290#	C	0.054#	C	0.299#
11	3.900	49	1.571	A	0.048	A	0.403
12	6.264	45	1.900	B	0.059	B	0.303
13	5.031	43	1.838	L	0.050	L	0.365
14	0.656	40	1.190	E	0.000	E	1.814
15	2.861	59	0.884		0.054		0.309
16	2.687	63	0.983		0.057		0.366
17	6.495	44	1.490		0.063		0.229
18	1.143	41	1.063		0.005		0.931
19	4.017	52	1.304		0.051		0.325
20	4.775	52	1.405		0.059		0.294
21	5.383	58	2.631		0.064		0.489
22	2.216	52	1.112		0.036		0.502
23	4.004#	50#	1.370#		0.049#		0.342#
24	2.878	48	0.845		0.056		0.294
25	4.397	59	0.845		0.056		0.192
26	5.928	67	1.912		0.067		0.323
27	3.896	55	1.856		0.048		0.476
28	3.695	54	1.959		0.042		0.530
29	5.462	56	1.382		0.066		0.253
30	6.171	69	2.299		0.067		0.373
SUM	119.186	-	40.863	N.A.	1.460	N.A.	-
AVG	3.973	50	1.362	N.A.	0.049	N.A.	0.343
PFRV	0.8847	0.8847	0.8847	N.A.	0.8833	N.A.	0.8847

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	1.363	0.536	0.211	36	0.154	0.393
2	2.919	2.368	1.093	45	0.374	0.461
3	3.267	2.584	0.990	49	0.303	0.383
4	4.281	3.342	1.237	51	0.289	0.370
5	2.964	2.336	0.972	50	0.328	0.416
6	1.565	1.047	0.599	63	0.383	0.572
7	5.621	5.333	1.882	58	0.335	0.353
8	5.020	3.097	1.144	49	0.228	0.369
9	6.012	5.172	1.907	44	0.317	0.369
10	4.314#	3.476#	1.330#	55#	0.308#	0.383#
11	3.900	3.179	1.265	51	0.324	0.398
12	6.264	5.245	2.034	55	0.325	0.388
13	5.031	4.361	1.800	54	0.358	0.413
14	0.656	0.000	0.000	40	0.000	0.000
15	2.861	2.556	1.181	71	0.413	0.462
16	2.687	2.364	1.149	73	0.428	0.486
17	6.495	5.690	2.137	49	0.329	0.376
18	1.143	0.074	0.041	45	0.036	0.551
19	4.017	3.413	1.598	65	0.398	0.468
20	4.775	4.318	1.839	59	0.385	0.426
21	5.383	4.787	2.137	67	0.397	0.446
22	2.216	1.668	0.700	59	0.316	0.420
23	4.004#	3.302#	1.352#	58#	0.338#	0.410#
24	2.878	2.300	0.865	56	0.301	0.376
25	4.397	3.935	1.707	67	0.388	0.434
26	5.928	5.186	2.029	76	0.342	0.391
27	3.896	3.150	1.217	59	0.312	0.386
28	3.695	3.053	1.409	70	0.381	0.462
29	5.462	4.784	1.958	62	0.358	0.409
30	6.171	5.404	2.277	80	0.369	0.421
SUM	119.186	98.059	40.060@	-	-	-
AVG	3.973	3.269	1.335	57	0.336	0.409
PFRV	0.8847	0.8847	0.8847	0.8847	0.8847	0.8847

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	0.211	0.301	-0.167	64	0.97
2	1.093	0.726	0.395	64	0.35
3	0.990	0.867	0.186	75	0.41
4	1.237	0.994	0.327	81	0.43
5	0.972	1.130	-0.180	79	0.12
6	0.599	0.914	-0.336	69	0.32
7	1.882	0.018	2.078	100	0.64
8	1.144	2.865	-1.779	115	0.11
9	1.907	1.919	0.148	88	0.57
10	1.330#	1.290#	0.010	85#	0.13#
11	1.265	1.571	-0.749	89	1.75
12	2.034	1.900	0.251	100	0.33
13	1.800	1.838	-0.111	97	0.21
14	0.000	1.190	-1.135	74	0.32
15	1.181	0.884	0.403	68	1.85
16	1.149	0.983	0.167	75	0.02
17	2.137	1.490	0.751	95	0.36
18	0.041	1.063	-1.115	82	0.43
19	1.598	1.304	0.394	77	0.81
20	1.839	1.405	0.458	86	0.12
21	2.137	2.631	-0.213	95	1.05
22	0.700	1.112	-0.109	83	1.80
23	1.352#	1.370#	*	85#	*
24	0.865	0.845	-0.334	77	2.54
25	1.707	0.845	0.730	85	0.73
26	2.029	1.912	0.377	108	0.77
27	1.217	1.856	-0.620	96	0.07
28	1.409	1.959	-0.484	82	0.43
29	1.958	1.382	0.698	86	0.68
30	2.277	2.299	0.185	102	0.73
SUM	40.060@	40.863	1.196	-	-
AVG	1.335	1.362	0.040	85	0.66
PFRV	0.8847	0.8847	N.A.	0.8847	0.8847

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

@ SEE APRIL PERFORMANCE REPORT

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	3.168	9	0.300	0.050	3.137	N	4.482	N	0.429	48	157	3223
2	2.733	27	0.726	0.032	2.317	O	3.310	O	1.037	47	163	2570
3	2.243	39	0.867	0.016	1.709	T	2.442	T	1.239	47	166	2013
4	2.326	43	0.993	0.012	1.229		1.756		1.419	47	165	2111
5	3.025	37	1.130	0.020	1.781	A	2.544	A	1.614	47	164	2844
6	4.103	22	0.914	0.023	2.867	P	4.095	P	1.306	47	162	4016
7	0.283	6	0.017	0.002	0.306	P	0.438	P	0.025	63	177	39
8	3.578	80	2.865	0.009	0.659	L	0.941	L	4.092	48	167	3361
9	3.094	62	1.919	0.018	0.920	I	1.315	I	2.741	48	164	2932
10	2.744#	45#	1.289#	0.025#	1.265#	C	1.808#	C	1.842#	49#	163#	2658#
11	2.922	52	1.571	0.024	1.151	A	1.644	A	2.244	49	163	2813
12	2.684	71	1.900	0.011	0.862	B	1.232	B	2.714	48	166	2482
13	3.129	59	1.838	0.017	1.106	L	1.581	L	2.626	48	164	2990
14	4.140	29	1.189	0.039	1.278	E	1.826	E	1.699	48	161	4153
15	3.125	28	0.883	0.028	1.644		2.348		1.262	49	163	3010
16	3.115	32	0.983	0.028	1.381		1.973		1.404	49	163	3029
17	2.472	60	1.489	0.013	0.700		1.000		2.128	49	165	2306
18	2.420	44	1.063	0.019	1.416		2.023		1.519	48	164	2248
19	2.996	44	1.304	0.025	1.651		2.359		1.863	49	163	2873
20	3.313	42	1.404	0.024	1.374		1.963		2.006	49	162	3234
21	4.289	61	2.630	0.021	1.450		2.072		3.758	49	163	4232
22	2.905	38	1.111	0.033	1.445		2.065		1.588	49	161	2873
23	2.908#	45#	1.370#	0.029#	1.345#		1.921#		1.957#	49#	163#	2842#
24	2.566	32	0.845	0.034	1.310		1.871		1.207	50	160	2547
25	1.594	53	0.844	0.062	0.661		0.944		1.206	50	150	1612
26	2.242	85	1.911	0.062	0.441		0.630		2.731	52	155	2331
27	3.373	55	1.856	0.014	1.338		1.912		2.651	50	165	3264
28	4.239	46	1.958	0.024	2.010		2.871		2.798	50	162	4280
29	2.846	49	1.381	0.042	1.261		1.801		1.973	51	154	3020
30	2.401	96	2.299	0.126	0.003		0.004		3.284	52	135	3117
SUM	86.991	-	40.863	0.896	40.030	N.A.	57.186	N.A.	58.376	-	-	85036
AVG	2.899	47	1.362	0.029	1.334	N.A.	1.906	N.A.	1.945	49	161	2834
PFRV	0.8847	0.885	0.8847	0.8833	0.8875	N.A.	0.8875	N.A.	0.8847	0.88	0.88	0.8847

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	3.168	9	2.922	18	0.301	0.050	3.138
2	2.734	27	2.487	23	0.726	0.033	2.317
3	2.244	39	1.997	34	0.867	0.016	1.710
4	2.327	43	2.080	44	0.994	0.012	1.230
5	3.026	37	2.779	46	1.130	0.021	1.781
6	4.104	22	3.857	25	0.914	0.023	2.867
7	0.284	6	0.037	15	0.018	0.002	0.307
8	3.578	80	3.331	75	2.865	0.010	0.659
9	3.095	62	2.848	70	1.919	0.018	0.921
10	2.744#	45#	2.498#	50#	1.290#	0.026#	1.266#
11	2.923	52	2.676	53	1.571	0.025	1.151
12	2.684	71	2.437	74	1.900	0.012	0.863
13	3.130	59	2.883	63	1.838	0.017	1.107
14	4.141	29	3.894	60	1.190	0.040	1.278
15	3.126	28	2.879	34	0.884	0.029	1.644
16	3.115	32	2.869	45	0.983	0.029	1.381
17	2.472	60	2.225	61	1.490	0.013	0.701
18	2.420	44	2.174	49	1.063	0.019	1.417
19	2.997	44	2.750	42	1.304	0.025	1.651
20	3.314	42	3.067	50	1.405	0.024	1.375
21	4.289	61	4.043	65	2.631	0.021	1.451
22	2.905	38	2.659	47	1.112	0.034	1.446
23	2.909#	45#	2.662#	50#	1.370#	0.030#	1.345#
24	2.566	32	2.319	40	0.845	0.034	1.310
25	1.594	53	1.347	52	0.845	0.062	0.661
26	2.242	85	1.996	81	1.912	0.063	0.442
27	3.373	55	3.127	60	1.856	0.015	1.339
28	4.240	46	3.993	52	1.959	0.024	2.010
29	2.847	49	2.600	50	1.382	0.042	1.261
30	2.402	96	2.155	97	2.299	0.127	0.003
SUM	86.991	-	79.590	-	40.863	0.897	40.031
AVG	2.900	47	2.653	52	1.362	0.030	1.334
PFRV	0.8847	0.8847	0.8847	0.8847	0.8847	0.8833	0.8875

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	4.483	N	0.430	48	157	3618	3223	N
2	O	3.310	O	1.038	47	163	2719	2571	O
3	T	2.443	T	1.239	47	166	2264	2013	T
4		1.757		1.419	47	165	2445	2111	
5	A	2.545	A	1.614	47	164	3338	2844	A
6	P	4.096	P	1.306	47	162	4498	4017	P
7	P	0.438	P	0.025	63	177	0	39	P
8	L	0.941	L	4.093	48	167	3799	3362	L
9	I	1.315	I	2.742	48	164	3335	2932	I
10	C	1.809#	C	1.842#	49#	163#	2940#	2659#	C
11	A	1.645	A	2.245	49	163	3141	2814	A
12	B	1.232	B	2.715	48	166	2885	2482	B
13	L	1.581	L	2.626	48	164	3324	2990	L
14	E	1.826	E	1.700	48	161	4349	4153	E
15		2.349		1.263	49	163	3345	3010	
16		1.973		1.405	49	163	3345	3030	
17		1.001		2.128	49	165	2507	2307	
18		2.024		1.519	48	164	2476	2248	
19		2.359		1.863	49	163	3050	2873	
20		1.964		2.007	49	162	3511	3235	
21		2.072		3.758	49	163	4768	4232	
22		2.065		1.588	49	161	3279	2874	
23		1.921#		1.958#	49#	163#	3160#	2842#	
24		1.872		1.208	50	160	2991	2547	
25		0.945		1.207	50	150	1921	1613	
26		0.631		2.731	52	155	2585	2332	
27		1.912		2.652	50	165	3600	3264	
28		2.872		2.798	50	162	4644	4281	
29		1.802		1.974	51	154	3422	3020	
30		0.005		3.284	52	135	3318	3118	
SUM	N.A.	57.187	N.A.	58.376	-	-	94576	85037	N.A.
AVG	N.A.	1.906	N.A.	1.946	49	161	3153	2835	N.A.
PFRV	N.A.	0.8875	N.A.	0.8847	0.8847	0.8847	0.8847	0.8847	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - [illegible]-3121 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	532	N	39	36	N	N	N	29	0
2	1139	O	40	45	O	O	O	24	0
3	1275	T	41	49	T	T	T	23	0
4	1670		46	51				20	0
5	1157	A	45	50	A	A	A	17	0
6	611	P	53	63	P	P	P	10	0
7	2193	P	51	58	P	P	P	15	0
8	1958	L	41	49	L	L	L	23	0
9	2346	I	37	44	I	I	I	28	0
10	1683#	C	44#	55#	C	C	C	33	0
11	1522	A	49	51	A	A	A	15	0
12	2444	B	45	55	B	B	B	21	0
13	1963	L	43	54	L	L	L	22	0
14	256	E	40	40	E	E	E	25	0
15	1116		59	71				6	0
16	1048		63	73				3	0
17	2534		44	49				22	0
18	446		41	45				24	0
19	1567		52	65				12	0
20	1863		52	59				10	0
21	2100		58	67				6	0
22	865		52	59				10	0
23	1562#		50#	58#				*	*
24	1123		48	56				15	0
25	1716		59	67				7	0
26	2313		67	76				0	2
27	1520		55	59				11	0
28	1442		54	70				7	0
29	2131		56	62				9	0
30	2408		69	80				0	0
SUM	46503	N.A.	-	-	-	-	-	462	3
AVG	1550	N.A.	50	57	N.A.	N.A.	N.A.	15	0
PFRV	0.8847	N.A.	0.8847	0.8847	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 REPORT: MAY 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	126.262 MILLION BTU
	49263 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	43.742 MILLION BTU
	17067 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	61 DEGREES F
AVERAGE BUILDING TEMPERATURE	69 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	1.663 MILLION BTU
STORAGE EFFICIENCY	103.73 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.731 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	4.740 MILLION BTU
TOTAL ENERGY CONSUMED	104.694 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	80.715	N.A.	N.A.	80.715 MILLION BTU
SOLAR FRACTION	57	N.A.	N.A.	57 PERCENT
SOLAR ENERGY USED	45.884	N.A.	N.A.	45.884 MILLION BTU
OPERATING ENERGY	3.077	N.A.	N.A.	4.740 MILLION BTU
AUX. THERMAL ENERGY	39.320	N.A.	N.A.	39.320 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	56.172	N.A.	N.A.	56.172 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.663 MILLION BTU
FOSSIL SAVINGS	65.549	N.A.	N.A.	65.549 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.12

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 6.44

* = 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: MAY 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	133.206 GIGA JOULES
	559435 KJ/SQ.M.
COLLECTED SOLAR ENERGY	46.148 GIGA JOULES
	193809 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	16 DEGREES C
AVERAGE BUILDING TEMPERATURE	21 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.36
ECSS OPERATING ENERGY	1.755 GIGA JOULES
STORAGE EFFICIENCY	103.73 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	4.154 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	5.001 GIGA JOULES
TOTAL ENERGY CONSUMED	110.452 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	85.154	N.A.	N.A.	85.154 GIGA JOULES
SOLAR FRACTION	57	N.A.	N.A.	57 PERCENT
SOLAR ENERGY USED	48.408	N.A.	N.A.	48.408 GIGA JOULES
OPERATING ENERGY	3.246	N.A.	N.A.	5.001 GIGA JOULES
AUX. THERMAL ENG	41.483	N.A.	N.A.	41.483 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	59.261	N.A.	N.A.	59.261 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.755 GIGA JOULES
FOSSIL SAVINGS	69.154	N.A.	N.A.	69.154 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.12
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 6.44

* = 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: LAUNDERETTE, FORT DEVENS - P-3121 MAY 1985

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
(NBS ID)	(Q001)	(N113)			(Q102)		(N111)
1	3.794	66	1.712	N	0.050	N	0.451
2	4.058	54	1.348	O	0.055	O	0.332
3	0.656	42	0.574	T	0.000	T	0.874
4	5.834	53	1.092		0.066		0.187
5	1.885	58	1.742	A	0.044	A	0.924
6	0.357	45	0.204	P	0.000	P	0.573
7	3.625	57	0.792	P	0.065	P	0.218
8	6.553	50	1.115	L	0.064	L	0.170
9	6.170	55	2.000	I	0.068	I	0.324
10	5.372	72	1.924	C	0.068	C	0.358
11	5.639	79	1.746	A	0.072	A	0.310
12	2.600	55	2.181	B	0.039	B	0.839
13	3.767#	59#	1.419#	L	0.048#	L	0.377#
14	4.067#	61#	1.482#	E	0.054#	E	0.364#
15	6.155	63	2.352		0.068		0.382
16	2.823	63	1.187		0.049		0.421
17	2.016	63	0.779		0.053		0.387
18	1.039	54	0.480		0.018		0.462
19	3.310	53	1.099		0.054		0.332
20	5.760	70	1.561		0.070		0.271
21	3.263	69	2.019		0.057		0.619
22	6.293	67	2.316		0.073		0.368
23	5.275	63	2.089		0.073		0.396
24	6.269	67	1.961		0.072		0.313
25	5.007	68	1.286		0.068		0.257
26	4.346	62	2.159		0.053		0.497
27	4.257	69	0.052		0.066		0.012
28	0.638	59	1.990		0.000		3.118
29	6.137	56	1.597		0.077		0.260
30	5.251	64	1.789		0.072		0.341
31	4.046	68	1.837		0.052		0.454
SUM	126.262	-	45.884	N.A.	1.663	N.A.	-
AVG	4.073	61	1.480	N.A.	0.054	N.A.	0.363
PFRV	0.9355	0.9355	0.9355	N.A.	0.9355	N.A.	0.9355

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	3.794	3.156	1.395	77	0.368	0.442
2	4.058	3.495	1.392	61	0.343	0.398
3	0.656	0.000	0.000	42	0.000	0.000
4	5.834	4.958	2.073	66	0.355	0.418
5	1.885	1.493	0.618	69	0.328	0.414
6	0.357	0.000	0.000	46	0.000	0.000
7	3.625	3.169	1.293	63	0.357	0.408
8	6.553	5.476	1.994	52	0.304	0.364
9	6.170	5.473	1.794	64	0.291	0.328
10	5.372	4.741	1.822	81	0.339	0.384
11	5.639	5.167	2.096	89	0.372	0.406
12	2.600	1.662	0.687	55	0.264	0.414
13	3.767#	3.157#	1.297#	68#	0.344#	0.411#
14	4.067#	3.468#	1.412#	68#	0.347#	0.407#
15	6.155	5.279	2.184	73	0.355	0.414
16	2.823	2.369	1.033	72	0.366	0.436
17	2.016	1.513	0.779	67	0.386	0.515
18	1.039	0.353	0.138	55	0.133	0.391
19	3.310	2.655	1.193	58	0.360	0.449
20	5.760	5.292	2.366	81	0.411	0.447
21	3.263	2.937	1.195	81	0.366	0.407
22	6.293	5.743	2.392	72	0.380	0.417
23	5.275	4.666	1.885	71	0.357	0.404
24	6.269	5.610	2.496	76	0.398	0.445
25	5.007	4.402	1.777	77	0.355	0.404
26	4.346	3.557	1.491	67	0.343	0.419
27	4.257	3.987	1.473	85	0.346	0.370
28	0.638	0.000	0.000	59	0.000	0.000
29	6.137	5.780	2.381	61	0.388	0.412
30	5.251	4.604	1.768	76	0.337	0.384
31	4.046	3.294	1.316	77	0.325	0.399
SUM	126.262	107.453	43.742	-	-	-
AVG	4.073	3.466	1.411	68	0.346	0.407
PERV	0.9355	0.9355	0.9355	0.9355	0.9355	0.9355

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	1.395	1.712	-0.415	94	0.47
2	1.392	1.348	0.121	88	0.37
3	0.000	0.574	-0.702	75	0.93
4	2.073	1.092	1.022	87	0.20
5	0.618	1.742	-0.910	83	1.39
6	0.000	0.204	-0.233	63	1.79
7	1.293	0.792	0.680	75	1.78
8	1.994	1.115	0.673	101	0.60
9	1.794	2.000	0.078	114	0.62
10	1.822	1.924	-0.066	111	0.10
11	2.096	1.746	0.339	114	0.03
12	0.687	2.181	-1.310	95	0.73
13	1.297#	1.419#	-0.009	87#	0.65#
14	1.412#	1.482#	*	91#	*
15	2.184	2.352	-0.024	93	0.64
16	1.033	1.187	-0.092	78	0.76
17	0.779	0.779	-0.002	73	0.05
18	0.138	0.480	-0.326	66	0.51
19	1.193	1.099	0.288	69	3.89
20	2.366	1.561	0.891	93	0.46
21	1.195	2.019	-0.758	94	0.34
22	2.392	2.316	0.281	93	1.04
23	1.885	2.089	-0.015	94	0.87
24	2.496	1.961	0.555	99	0.08
25	1.777	1.286	0.156	106	1.08
26	1.491	2.159	-0.464	101	0.71
27	1.473	0.052	1.237	112	0.51
28	0.000	1.990	-1.987	94	0.01
29	2.381	1.597	1.046	90	1.25
30	1.768	1.789	-0.037	103	0.05
31	1.316	1.837	-0.527	94	0.03
SUM	43.742	45.884	-0.510	-	-
AVG	1.411	1.480	-0.016	91	0.73
PFRV	0.9355	0.9355	N.A.	0.9355	0.9355

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	2.759	62	1.712	0.063	1.094	N	1.563	N	2.446	52	158	2834
2	2.973	45	1.348	0.046	1.659	O	2.370	O	1.925	51	164	2892
3	1.905	30	0.573	0.061	1.433	T	2.047	T	0.819	52	164	1769
4	2.200	50	1.091	0.012	1.195		1.707		1.559	52	165	2062
5	3.920	44	1.742	0.073	2.333	A	3.333	A	2.488	52	158	4162
6	1.962	10	0.204	0.066	2.347	P	3.353	P	0.292	52	166	1808
7	2.285	35	0.791	0.015	1.501	P	2.144	P	1.131	52	164	2169
8	1.764	63	1.114	0.010	1.100	L	1.571	L	1.592	51	167	1573
9	2.314	86	2.000	0.065	0.153	I	0.219	I	2.857	51	162	2228
10	2.314	83	1.924	0.098	0.661	C	0.945	C	2.748	51	160	2276
11	2.306	76	1.745	0.080	0.642	A	0.918	A	2.494	51	160	2267
12	3.672	59	2.180	0.126	1.735	B	2.479	B	3.115	52	163	3694
13	2.488#	55#	1.418#	0.109#	1.225#	L	1.750#	L	2.026#	55#	148#	2918#
14	2.606#	55#	1.482#	0.099#	1.267#	E	1.810#	E	2.117#	55#	148#	3113#
15	2.748	85	2.352	0.119	0.666		0.952		3.360	55	141	3528
16	2.819	42	1.187	0.126	1.831		2.616		1.695	53	140	3538
17	2.716	29	0.779	0.127	2.186		3.122		1.113	54	138	3509
18	3.229	15	0.480	0.126	3.200		4.571		0.685	54	137	4290
19	4.227	26	1.098	0.126	3.436		4.909		1.569	54	135	5873
20	2.336	67	1.560	0.125	0.855		1.222		2.229	56	135	3137
21	2.989	68	2.019	0.127	0.954		1.363		2.884	54	139	3879
22	2.829	82	2.316	0.126	0.609		0.870		3.309	56	138	3762
23	2.662	78	2.089	0.126	0.658		0.940		2.984	57	135	3714
24	2.515	78	1.961	0.126	0.691		0.987		2.802	55	136	3352
25	1.818	71	1.286	0.126	0.486		0.694		1.837	57	139	2316
26	2.675	81	2.158	0.126	0.518		0.740		3.083	56	138	3567
27	0.310	17	0.051	0.126	0.206		0.294		0.073	94	138	175
28	3.588	55	1.990	0.127	1.674		2.392		2.842	57	138	4935
29	2.592	62	1.596	0.127	1.254		1.792		2.281	59	138	3596
30	2.302	78	1.789	0.126	0.594		0.849		2.556	64	138	3371
31	2.876	64	1.836	0.124	1.143		1.633		2.624	62	140	4085
SUM	80.714	-	45.884	3.076	39.320	N.A.	56.171	N.A.	65.549	-	-	96404
AVG	2.603	57	1.480	0.099	1.268	N.A.	1.811	N.A.	2.114	55	146	3109
PFRV	0.9355	0.935	0.9355	0.9355	0.9368	N.A.	0.9368	N.A.	0.9355	0.94	0.94	0.9355

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	2.760	62	2.513	67	1.712	0.064	1.095
2	2.973	45	2.726	47	1.348	0.046	1.659
3	1.905	30	1.658	36	0.574	0.061	1.433
4	2.200	50	1.953	45	1.092	0.012	1.195
5	3.921	44	3.674	47	1.742	0.073	2.333
6	1.963	10	1.716	10	0.204	0.066	2.347
7	2.285	35	2.038	31	0.792	0.015	1.501
8	1.764	63	1.518	56	1.115	0.011	1.100
9	2.314	86	2.068	86	2.000	0.066	0.153
10	2.315	83	2.068	79	1.924	0.098	0.662
11	2.306	76	2.060	72	1.746	0.080	0.643
12	3.673	59	3.426	60	2.181	0.127	1.735
13	2.488#	55#	2.241#	56#	1.419#	0.109#	1.225#
14	2.607#	55#	2.360#	55#	1.482#	0.099#	1.267#
15	2.749	85	2.502	80	2.352	0.120	0.666
16	2.820	42	2.573	43	1.187	0.127	1.832
17	2.716	29	2.469	28	0.779	0.127	2.186
18	3.230	15	2.983	14	0.480	0.127	3.200
19	4.227	26	3.980	25	1.099	0.126	3.437
20	2.337	67	2.090	62	1.561	0.126	0.856
21	2.990	68	2.743	70	2.019	0.127	0.955
22	2.830	82	2.583	80	2.316	0.126	0.610
23	2.662	78	2.416	77	2.089	0.127	0.659
24	2.516	78	2.269	76	1.961	0.127	0.691
25	1.819	71	1.572	72	1.286	0.127	0.486
26	2.676	81	2.429	82	2.159	0.127	0.519
27	0.311	17	0.064	46	0.052	0.127	0.206
28	3.588	55	3.341	58	1.990	0.127	1.674
29	2.593	62	2.346	56	1.597	0.127	1.254
30	2.303	78	2.056	72	1.789	0.127	0.595
31	2.876	64	2.629	63	1.837	0.125	1.143
SUM	80.715	-	73.067	-	45.884	3.077	39.320
AVG	2.604	57	2.357	56	1.480	0.099	1.268
PFRV	0.9355	0.9355	0.9355	0.9355	0.9355	0.9355	0.9368

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	1.564	N	2.446	52	158	3207	2834	N
2	O	2.370	O	1.926	51	164	3632	2893	O
3	T	2.048	T	0.819	52	164	2648	1769	T
4		1.707		1.559	52	165	2953	2062	
5	A	3.333	A	2.489	52	158	5249	4163	A
6	P	3.353	P	0.292	52	166	2827	1808	P
7	P	2.145	P	1.131	52	164	3156	2170	P
8	L	1.572	L	1.593	51	167	2510	1574	L
9	I	0.219	I	2.858	51	162	3043	2228	I
10	C	0.945	C	2.749	51	160	3044	2276	C
11	A	0.918	A	2.494	51	160	2905	2267	A
12	B	2.479	B	3.115	52	163	4936	3694	B
13	L	1.750#	L	2.027#	55#	148#	3257#	2919#	L
14	E	1.811#	E	2.117#	55#	148#	3405#	3114#	E
15		0.952		3.360	55	141	3156	3528	
16		2.617		1.696	53	140	3430	3538	
17		3.123		1.113	54	138	3451	3509	
18		4.572		0.686	54	137	4348	4291	
19		4.910		1.569	54	135	6187	5873	
20		1.222		2.230	56	135	3181	3137	
21		1.364		2.885	54	139	3941	3879	
22		0.871		3.309	56	138	3576	3763	
23		0.941		2.984	57	135	3533	3714	
24		0.987		2.802	55	136	3500	3352	
25		0.695		1.837	57	139	2350	2316	
26		0.741		3.084	56	138	3451	3567	
27		0.295		0.074	94	138	11	176	
28		2.392		2.843	57	138	4757	4936	
29		1.792		2.281	59	138	3437	3597	
30		0.850		2.556	64	138	2924	3372	
31		1.633		2.624	62	140	3430	4085	
SUM	N.A.	56.172	N.A.	65.549	-	-	105434	96405	N.A.
AVG	N.A.	1.812	N.A.	2.114	55	146	3401	3110	N.A.
PFRV	N.A.	0.9368	N.A.	0.9355	0.9355	0.9355	0.9355	0.9355	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121 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	1480	N	66	77	N	N	N	0	4
2	1583	O	54	61	O	O	O	10	0
3	256	T	42	42	T	T	T	23	0
4	2276		53	66				15	0
5	736	A	58	69	A	A	A	6	0
6	139	P	45	46	P	P	P	20	0
7	1414	P	57	63	P	P	P	9	0
8	2557	L	50	52	L	L	L	19	0
9	2407	I	55	64	I	I	I	15	0
10	2096	C	72	81	C	C	C	0	5
11	2200	A	79	89	A	A	A	0	12
12	1014	B	55	55	B	B	B	8	0
13	1470#	L	59#	68#	L	L	L	15	0
14	1587#	E	61#	68#	E	E	E	*	*
15	2402		63	73				1	0
16	1102		63	72				3	0
17	787		63	67				1	0
18	406		54	55				13	0
19	1292		53	58				11	0
20	2247		70	81				0	2
21	1273		69	81				0	7
22	2455		67	72				0	1
23	2058		63	71				3	0
24	2446		67	76				0	0
25	1954		68	77				0	2
26	1696		62	67				3	0
27	1661		69	85				0	6
28	249		59	59				6	0
29	2394		56	61				8	0
30	2049		64	76				4	0
31	1579		68	77				0	2
SUM	49263	N.A.	-	-	-	-	-	202	42
AVG	1589	N.A.	61	68	N.A.	N.A.	N.A.	7	1
PFRV	0.9355	N.A.	0.9355	0.9355	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 REPORT: JUNE 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	110.803 MILLION BTU
	43232 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	39.991 MILLION BTU
	15603 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	65 DEGREES F
AVERAGE BUILDING TEMPERATURE	72 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.40
ECSS OPERATING ENERGY	1.633 MILLION BTU
STORAGE EFFICIENCY	110.29 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	2.015 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	5.430 MILLION BTU
TOTAL ENERGY CONSUMED	127.404 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	92.723	N.A.	N.A.	92.723 MILLION BTU
SOLAR FRACTION	47	N.A.	N.A.	47 PERCENT
SOLAR ENERGY USED	43.770	N.A.	N.A.	43.770 MILLION BTU
OPERATING ENERGY	3.797	N.A.	N.A.	5.430 MILLION BTU
AUX. THERMAL ENERGY	57.388	N.A.	N.A.	57.388 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	81.983	N.A.	N.A.	81.983 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.633 MILLION BTU
FOSSIL SAVINGS	62.529	N.A.	N.A.	62.529 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.93
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.14

* = 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: JUNE 1985
SITE SUMMARY: LAUNDERETTE, FORT DEVENS - P-3121R

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	116.898 GIGA JOULES
	490942 KJ/SQ.M.
COLLECTED SOLAR ENERGY	42.191 GIGA JOULES
	177190 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	18 DEGREES C
AVERAGE BUILDING TEMPERATURE	22 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.40
ECSS OPERATING ENERGY	1.722 GIGA JOULES
STORAGE EFFICIENCY	110.29 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	11.441 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	5.728 GIGA JOULES
TOTAL ENERGY CONSUMED	134.411 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	97.823	N.A.	N.A.	97.823 GIGA JOULES
SOLAR FRACTION	47	N.A.	N.A.	47 PERCENT
SOLAR ENERGY USED	46.178	N.A.	N.A.	46.178 GIGA JOULES
OPERATING ENERGY	4.006	N.A.	N.A.	5.728 GIGA JOULES
AUX. THERMAL ENG	60.544	N.A.	N.A.	60.544 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	86.492	N.A.	N.A.	86.492 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.722 GIGA JOULES
FOSSIL SAVINGS	65.968	N.A.	N.A.	65.968 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.93

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.14

* = 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: LAUNDERETTE, FORT DEVENS - P-3121R 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	4.511	68	1.612	N	0.070	N	0.357
2	6.140	71	2.869	O	0.076	O	0.467
3	3.708	72	1.482	T	0.052	T	0.400
4	5.709	66	1.888		0.073		0.331
5	1.150	54	0.726	A	0.007	A	0.631
6	2.588	56	0.798	P	0.047	P	0.308
7	6.339	64	2.266	P	0.069	P	0.357
8	2.070	62	1.011	L	0.044	L	0.488
9	4.874	70	2.239	I	0.067	I	0.459
10	6.277	74	2.577	C	0.075	C	0.411
11	5.683	71	1.902	A	0.071	A	0.335
12	0.701	56	0.518	B	0.001	B	0.738
13	2.177	57	0.472	L	0.044	L	0.217
14	4.929	61	1.693	E	0.070	E	0.343
15	5.794	66	1.940		0.077		0.335
16	1.486	64	1.304		0.049		0.877
17	3.345	67	1.381		0.064		0.413
18	2.038	71	0.965		0.058		0.474
19	5.471	71	1.965		0.074		0.359
20	5.096	69	1.923		0.066		0.377
21	5.217	69	1.857		0.068		0.356
22	5.829	73	2.395		0.074		0.411
23	2.621	72	1.762		0.065		0.672
24	2.040	70	0.884		0.052		0.434
25	3.359	62	1.300		0.053		0.387
26	2.348	57	0.792		0.031		0.337
27	0.863	54	0.297		0.000		0.344
28	1.514	59	0.451		0.038		0.298
29	1.195	58	0.468		0.025		0.392
30	5.730	66	2.034		0.071		0.355
SUM	110.803	-	43.770	N.A.	1.633	N.A.	-
AVG	3.693	65	1.459	N.A.	0.054	N.A.	0.395
PFRV	0.9986	0.9986	0.9986	N.A.	0.9986	N.A.	0.9986

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	4.511	4.022	1.681	75	0.373	0.418
2	6.140	5.695	2.510	79	0.409	0.441
3	3.708	3.226	1.564	84	0.422	0.485
4	5.709	5.181	2.063	74	0.361	0.398
5	1.150	0.137	0.087	59	0.076	0.636
6	2.588	1.652	0.756	60	0.292	0.458
7	6.339	5.584	2.355	72	0.372	0.422
8	2.070	1.412	0.603	67	0.291	0.427
9	4.874	4.321	1.993	79	0.409	0.461
10	6.277	5.795	2.477	81	0.395	0.427
11	5.683	4.952	1.996	79	0.351	0.403
12	0.701	0.019	0.008	56	0.012	0.439
13	2.177	1.489	0.667	63	0.307	0.448
14	4.929	4.197	1.682	68	0.341	0.401
15	5.794	5.354	2.192	76	0.378	0.409
16	1.486	1.117	0.523	69	0.352	0.468
17	3.345	2.992	1.295	71	0.387	0.433
18	2.038	1.691	0.761	75	0.373	0.450
19	5.471	4.995	2.123	76	0.388	0.425
20	5.096	4.322	1.719	79	0.337	0.398
21	5.217	4.499	1.828	77	0.350	0.406
22	5.829	5.244	2.359	85	0.405	0.450
23	2.621	2.262	1.042	78	0.397	0.461
24	2.040	1.471	0.722	75	0.354	0.491
25	3.359	2.736	1.185	68	0.353	0.433
26	2.348	1.534	0.648	63	0.276	0.423
27	0.863	0.000	0.000	52	0.000	0.000
28	1.514	0.997	0.478	61	0.316	0.479
29	1.195	0.296	0.273	58	0.229	0.922
30	5.730	5.234	2.401	75	0.419	0.459
SUM	110.803	92.426	39.991	-	-	-
AVG	3.693	3.081	1.333	71	0.361	0.433
PFRV	0.9986	0.9986	0.9986	0.9986	0.9986	0.9986

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	1.681	1.612	0.183	87	0.93
2	2.510	2.869	-0.118	92	1.44
3	1.564	1.482	0.151	91	0.48
4	2.063	1.888	0.395	99	0.93
5	0.087	0.726	-0.833	79	1.63
6	0.756	0.798	0.068	77	1.21
7	2.355	2.266	0.345	95	1.11
8	0.603	1.011	-0.384	78	0.27
9	1.993	2.239	0.066	84	3.04
10	2.477	2.577	0.172	92	1.87
11	1.996	1.902	0.246	97	0.78
12	0.008	0.518	-0.596	76	1.18
13	0.667	0.472	0.304	77	1.32
14	1.682	1.693	0.108	87	0.81
15	2.192	1.940	0.396	95	0.74
16	0.523	1.304	-0.813	79	0.34
17	1.295	1.381	0.271	80	5.32
18	0.761	0.965	-0.136	78	1.54
19	2.123	1.965	0.285	89	1.02
20	1.719	1.923	-0.034	94	0.98
21	1.828	1.857	0.257	96	1.41
22	2.359	2.395	0.191	98	1.17
23	1.042	1.762	-0.686	83	0.42
24	0.722	0.884	-0.007	75	11.64
25	1.185	1.300	-0.000	80	1.50
26	0.648	0.792	-0.059	76	1.14
27	0.000	0.297	-0.243	67	1.68
28	0.478	0.451	0.202	68	10.90
29	0.273	0.468	-0.131	71	1.60
30	2.401	2.034	0.693	90	2.06
SUM	39.991	43.770	0.337	-	-
AVG	1.333	1.459	0.011	84	2.01
PFRV	0.9986	0.9986	N.A.	0.9986	0.9986

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	3.157	51	1.611	0.126	1.862	N	2.660	N	2.302	58	138	4349
2	4.072	70	2.869	0.126	1.274	O	1.820	O	4.099	59	136	5913
3	2.519	59	1.481	0.125	1.344	T	1.921	T	2.116	62	137	3636
4	2.627	72	1.887	0.126	0.905		1.293		2.696	66	138	3948
5	2.536	29	0.725	0.126	2.190	A	3.128	A	1.036	66	140	3733
6	3.013	26	0.798	0.126	2.630	P	3.758	P	1.140	66	139	4515
7	2.959	77	2.265	0.126	0.940	P	1.343	P	3.236	65	142	4251
8	3.045	33	1.010	0.126	2.307	L	3.296	L	1.443	59	139	4173
9	3.806	59	2.239	0.126	1.873	I	2.677	I	3.199	56	139	5159
10	3.218	80	2.576	0.125	0.710	C	1.014	C	3.681	56	137	4398
11	2.287	83	1.902	0.126	0.510	A	0.729	A	2.717	60	138	3147
12	2.247	23	0.517	0.126	2.133	B	3.047	B	0.739	63	139	3156
13	2.286	21	0.471	0.126	2.243	L	3.204	L	0.673	66	139	3362
14	2.950	57	1.692	0.126	1.507	E	2.153	E	2.418	59	139	4056
15	3.148	62	1.939	0.126	1.308		1.868		2.770	57	139	4241
16	4.129	32	1.303	0.126	3.028		4.325		1.862	57	136	5873
17	3.590	38	1.381	0.125	2.544		3.635		1.973	61	137	5287
18	2.941	33	0.965	0.126	2.277		3.253		1.378	59	138	4085
19	2.794	70	1.964	0.126	0.965		1.379		2.806	60	136	4036
20	2.830	67	1.923	0.126	1.206		1.722		2.747	65	136	4378
21	2.732	68	1.857	0.126	1.043		1.490		2.653	66	136	4271
22	3.358	71	2.394	0.126	1.074		1.535		3.421	63	135	5180
23	4.692	38	1.762	0.126	3.094		4.420		2.517	58	137	6753
24	2.965	30	0.884	0.124	2.465		3.522		1.263	58	136	4144
25	3.109	42	1.300	0.126	2.166		3.095		1.857	60	140	4300
26	2.471	32	0.791	0.126	2.072		2.960		1.130	62	139	3450
27	3.042	10	0.297	0.126	3.194		4.563		0.424	60	138	4319
28	3.178	14	0.451	0.125	3.202		4.575		0.644	60	136	4622
29	3.686	13	0.468	0.126	3.709		5.298		0.669	63	135	5707
30	3.323	61	2.033	0.126	1.599		2.285		2.905	62	137	4974
SUM	92.723	-	43.770	3.797	57.387	N.A.	81.982	N.A.	62.529	-	-	133428
AVG	3.090	47	1.459	0.126	1.912	N.A.	2.732	N.A.	2.084	61	138	4447
PFRV	0.9986	0.999	0.9986	0.9986	0.9986	N.A.	0.9986	N.A.	0.9986	1.00	1.00	0.9986

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	3.157	51	2.911	50	1.612	0.127	1.863
2	4.072	70	3.826	70	2.869	0.127	1.275
3	2.519	59	2.273	54	1.482	0.126	1.345
4	2.627	72	2.380	64	1.888	0.127	0.906
5	2.536	29	2.289	28	0.726	0.126	2.190
6	3.013	26	2.766	26	0.798	0.127	2.631
7	2.960	77	2.713	71	2.266	0.127	0.941
8	3.046	33	2.799	33	1.011	0.127	2.307
9	3.807	59	3.560	57	2.239	0.127	1.874
10	3.219	80	2.972	78	2.577	0.126	0.710
11	2.288	83	2.041	78	1.902	0.127	0.511
12	2.247	23	2.000	23	0.513	0.126	2.133
13	2.286	21	2.039	19	0.472	0.127	2.243
14	2.950	57	2.703	55	1.693	0.127	1.508
15	3.148	62	2.901	60	1.940	0.127	1.308
16	4.129	32	3.882	33	1.304	0.127	3.028
17	3.590	38	3.343	37	1.381	0.125	2.545
18	2.942	33	2.695	31	0.965	0.127	2.277
19	2.795	70	2.548	68	1.965	0.126	0.966
20	2.831	67	2.584	66	1.923	0.127	1.206
21	2.733	68	2.486	64	1.857	0.127	1.043
22	3.358	71	3.112	70	2.395	0.127	1.075
23	4.693	38	4.446	37	1.762	0.127	3.095
24	2.965	30	2.718	27	0.884	0.125	2.456
25	3.109	42	2.862	39	1.300	0.127	2.157
26	2.472	32	2.225	31	0.792	0.126	2.072
27	3.042	10	2.796	10	0.297	0.127	3.194
28	3.179	14	2.932	14	0.451	0.126	3.203
29	3.687	13	3.440	12	0.468	0.127	3.709
30	3.323	61	3.077	60	2.034	0.127	1.600
SUM	92.723	-	85.322	-	43.770	3.797	57.358
AVG	3.091	47	2.844	46	1.459	0.127	1.913
PFRV	0.9986	0.9986	0.9986	0.9986	0.9986	0.9986	0.9986

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MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	2.661	N	2.303	58	138	4222	4349	N
2	O	1.821	O	4.099	59	136	5277	5913	O
3	T	1.921	T	2.116	62	137	3009	3636	T
4		1.294		2.697	66	138	3140	3949	
5	A	3.129	A	1.037	66	140	2774	3734	A
6	P	3.758	P	1.140	66	139	3501	4515	P
7	P	1.344	P	3.237	65	142	3267	4252	P
8	L	3.296	L	1.444	59	139	3647	4173	L
9	I	2.677	I	3.199	56	139	4839	5160	I
10	C	1.014	C	3.681	56	137	4154	4398	C
11	A	0.730	A	2.717	60	138	2638	3147	A
12	B	3.048	B	0.739	63	139	2474	3157	B
13	L	3.205	L	0.674	66	139	2586	3362	L
14	E	2.154	E	2.418	59	139	3680	4056	E
15		1.869		2.771	57	139	4164	4242	
16		4.326		1.863	57	136	5579	5873	
17		3.635		1.973	61	137	4468	5287	
18		3.253		1.379	59	138	3730	4085	
19		1.380		2.806	60	136	3718	4036	
20		1.723		2.747	65	136	3780	4378	
21		1.490		2.653	66	136	3564	4271	
22		1.535		3.421	63	135	4569	5180	
23		4.421		2.518	58	137	6375	6753	
24		3.522		1.263	58	136	3864	4144	
25		3.095		1.858	60	140	3758	4301	
26		2.960		1.131	62	139	2902	3450	
27		4.563		0.424	60	138	4083	4320	
28		4.575		0.644	60	136	4279	4623	
29		5.299		0.669	63	135	5221	5707	
30		2.285		2.906	62	137	4607	4975	
SUM	N.A.	81.983	N.A.	62.529	-	-	117868	133429	N.A.
AVG	N.A.	2.733	N.A.	2.084	61	138	3929	4448	N.A.
PFRV	N.A.	0.9986	N.A.	0.9986	0.9986	0.9986	0.9986	0.9986	N.A.

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

MONTHLY REPORT: LAUNDERETTE, FORT DEVENS - P-3121R 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	1760	N	68	75	N	N	N	0	4
2	2396	O	71	79	O	O	O	0	4
3	1447	T	72	84	T	T	T	0	8
4	2227		66	74				0	0
5	449	A	54	59	A	A	A	9	0
6	1010	P	56	60	P	P	P	6	0
7	2473	P	64	72	P	P	P	3	0
8	808	L	62	67	L	L	L	0	1
9	1902	I	70	79	I	I	I	0	2
10	2449	C	74	81	C	C	C	0	9
11	2217	A	71	79	A	A	A	0	5
12	274	B	56	56	B	B	B	8	0
13	849	L	57	63	L	L	L	5	0
14	1923	E	61	68	E	E	E	4	0
15	2261		66	76				2	0
16	580		64	69				0	2
17	1305		67	71				0	5
18	795		71	75				0	8
19	2135		71	76				0	6
20	1988		69	79				0	3
21	2035		69	77				0	3
22	2274		73	85				0	7
23	1023		72	78				0	8
24	796		70	75				0	5
25	1311		62	68				1	0
26	916		57	63				7	0
27	337		54	52				11	0
28	591		59	61				5	0
29	466		58	58				6	0
30	2236		66	75				0	0
SUM	43232	N.A.	-	-	-	-	-	68	78
AVG	1441	N.A.	65	71	N.A.	N.A.	N.A.	2	3
PFRV	0.9986	N.A.	0.9986	0.9986	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 insolation 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. 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.

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

7. 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.

8. 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.

Table F-1. F-CHART PREDICTED INPUT PARAMETERS

FORT DEVENS

```
** FLAT PLATE COLLECTOR **
1  NUMBER OF COLLECTOR PANELS....   108
2  COLLECTOR PANEL AREA..........   23.73                  FT2
3  FR*UL (TEST SLOPE)............   .71                    BTU/HR-FT2-F

4  FR*TAU*ALPHA (TEST INTERCEPT).   .72
5  COLLECTOR SLOPE...............   35                     DEG
6  COLLECTOR AZIMUTH (SOUTH=0)... -19.5                    DEG
7  INCIDENCE ANGLE MOD TYPE(8-10)   9
8    NUMBER OF GLAZINGS..........   2
9    INC ANGLE MODIFIER CONSTANT.   .106
10   INC ANGLE MODIFIER VALUE(S).
  1    .999    .998    .995    .981    .953    .882
  .7    .35    0
11 COLLECTOR FLOWRATE/AREA.......   17.35                  LB/HR-FT2
12 COLLECTOR FLUID SPECIFIC HEAT.   .83                    BTU/LB-F
13 MODIFY TEST VALUES (1=Y,2=N)..   1
14   TEST COLLECTOR FLOWRATE/AREA   14.78                  LB/HR-FT2
15   TEST FLUID SPECIFIC HEAT....   1                      BTU/LB-F

*** GENERAL SOLAR HEATING SYSTEM ***
1  CITY CALL NUMBER..............   27
2  AVERAGE DAILY ENERGY USE......                          MMBTU/DAY
  2.6    2.88    2.99    2.9    2.6    3.09    2.87
  2.87    2.87    2.87    2.87    2.74
3  AVERAGE DAILY LOAD FLOW.......                          LB/DAY
  20600    22871    23126    23316    25595
  36599    25291    25291    25291    25291
  25291    23414
4  LOAD HEAT EX. EFFECTIVENESS...   1
5  MINIMUM USEFUL TEMPERATURE....   65                     F
6  LIQUID STORAGE TANK VOLUME....   3800                   GALLONS
7  TANK LIQUID SPECIFIC HEAT ....   1                      BTU/LB-F
8  TANK LIQUID DENSITY...........   62.4                   LB/FT3
9  UA OF SOLAR STORAGE TANK......   14.7                   BTU/HR-F
10 TANK ENVIRONMENT TEMPERATURE..                          F
  54    56    58    63    69    72    77    75    72    67
  62    58
11 FUEL (1=EL,2=NG,3=OIL,4=OTHER)   2
12 EFFICIENCY OF FUEL USAGE......   60                     %
13 PIPE HEAT LOSS (1=Y,2=N)......   1
14   INLET PIPE UA...............   8.05                   BTU/HR-F
15   OUTLET PIPE UA..............   7.02                   BTU/HR-F
16 COLLECTOR-STORAGE HX (1=Y,2=N)   1
17   TANK SIDE FLOWRATE/AREA.....   17.5                   LB/HR-FT2
18   HEAT EXCHANGER EFFECTIVENESS   .5
```

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

FORT DEVENS LAUNDERETTE

BOSTON MA LAT= 42.4

DEGREE-DAY BASE TEMPERATURE= 65 F

	SOLAR	TEMP	DEGDAY	MAINS	REFLEC	HUMID
	BTU/FT2	F	F-DAYS	F		LB/LB
JAN	498	29.1	1113	44.0	.20	.0027
FEB	841	31.0	969	45.0	.20	.0027
MAR	1293	40.0	835	45.0	.20	.0027
APR	1468	50.0	498	49.0	.20	.0039
MAY	1646	61.0	232	55.0	.20	.0057
JUN	1547	65.0	51	61.0	.20	.0101
JUL	1748	73.2	15	60.0	.20	.0124
AUG	1486	71.2	26	60.0	.20	.0108
SEP	1259	64.6	97	60.0	.20	.0088
OCT	889	55.4	317	55.0	.20	.0062
NOV	503	45.1	600	50.0	.20	.0034
DEC	428	33.1	989	47.0	.20	.0034

Table F-2. F-CHART MEASURED INPUT PARAMETERS

FORT DEVENS LAUNDERETTE

```
** FLAT PLATE COLLECTOR **
1  NUMBER OF COLLECTOR PANELS....   108
2  COLLECTOR PANEL AREA..........   23.73            FT2
3  FR*UL (TEST SLOPE)............   .68              BTU/HR-FT2-F

4  FR*TAU*ALPHA (TEST INTERCEPT).   .59
5  COLLECTOR SLOPE...............   35               DEG
6  COLLECTOR AZIMUTH (SOUTH=0)... -19.5             DEG
7  INCIDENCE ANGLE MOD TYPE(8-10)   9
8    NUMBER OF GLAZINGS..........   2
9    INC ANGLE MODIFIER CONSTANT.   0
10   INC ANGLE MODIFIER VALUE(S).
  1   .999   .998   .995   .981   .953   .882
  .7   .35   0
11 COLLECTOR FLOWRATE/AREA.......   17.35            LB/HR-FT2
12 COLLECTOR FLUID SPECIFIC HEAT.   .83              BTU/LB-F
13 MODIFY TEST VALUES (1=Y,2=N)..   2
14   TEST COLLECTOR FLOWRATE/AREA   14.78            LB/HR-FT2
15   TEST FLUID SPECIFIC HEAT....   1                BTU/LB-F

*** GENERAL SOLAR HEATING SYSTEM ***
1  CITY CALL NUMBER..............   27
2  AVERAGE DAILY ENERGY USE......                  MMBTU/DAY
  2.6   2.88   2.99   2.9   2.6   3.09   2.87
  2.87   2.87   2.87   2.87   2.74
3  AVERAGE DAILY LOAD FLOW.......                  LB/DAY
  20600   22871   23126   23316   25595
  36599   25291   25291   25291   25291
  25291   23414
4  LOAD HEAT EX. EFFECTIVENESS...   1
5  MINIMUM USEFUL TEMPERATURE....   65               F
6  LIQUID STORAGE TANK VOLUME....   3800             GALLONS
7  TANK LIQUID SPECIFIC HEAT ....   1                BTU/LB-F
8  TANK LIQUID DENSITY...........   62.4             LB/FT3
9  UA OF SOLAR STORAGE TANK......   22.5             BTU/HR-F
10 TANK ENVIRONMENT TEMPERATURE..                  F
  54   56   58   63   69   72   77   75   72   67
  62   58
11 FUEL (1=EL,2=NG,3=OIL,4=OTHER)   2
12 EFFICIENCY OF FUEL USAGE......   60               %
13 PIPE HEAT LOSS (1=Y,2=N)......   1
14   INLET PIPE UA...............   8.05             BTU/HR-F
15   OUTLET PIPE UA..............   7.02             BTU/HR-F
16 COLLECTOR-STORAGE HX (1=Y,2=N)   1
17   TANK SIDE FLOWRATE/AREA.....   17.5             LB/HR-FT2
18   HEAT EXCHANGER EFFECTIVENESS   .32
```

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

FORT DEVENS LAUNDERETTE

BOSTON MA LAT= 42.4

DEGREE-DAY BASE TEMPERATURE= 65 F

	SOLAR BTU/FT2	TEMP F	DEGDAY F-DAYS	MAINS F	REFLEC	HUMID LB/LB
JAN	498	29.1	1113	44.0	.20	.0027
FEB	841	31.0	969	45.0	.20	.0027
MAR	1293	40.0	835	45.0	.20	.0027
APR	1468	50.0	498	49.0	.20	.0039
MAY	1646	61.0	232	55.0	.20	.0057
JUN	1547	65.0	51	61.0	.20	.0101
JUL	1748	73.2	15	60.0	.20	.0124
AUG	1486	71.2	26	60.0	.20	.0108
SEP	1259	64.6	97	60.0	.20	.0088
OCT	889	55.4	317	55.0	.20	.0062
NOV	503	45.1	600	50.0	.20	.0034
DEC	428	33.1	989	47.0	.20	.0034