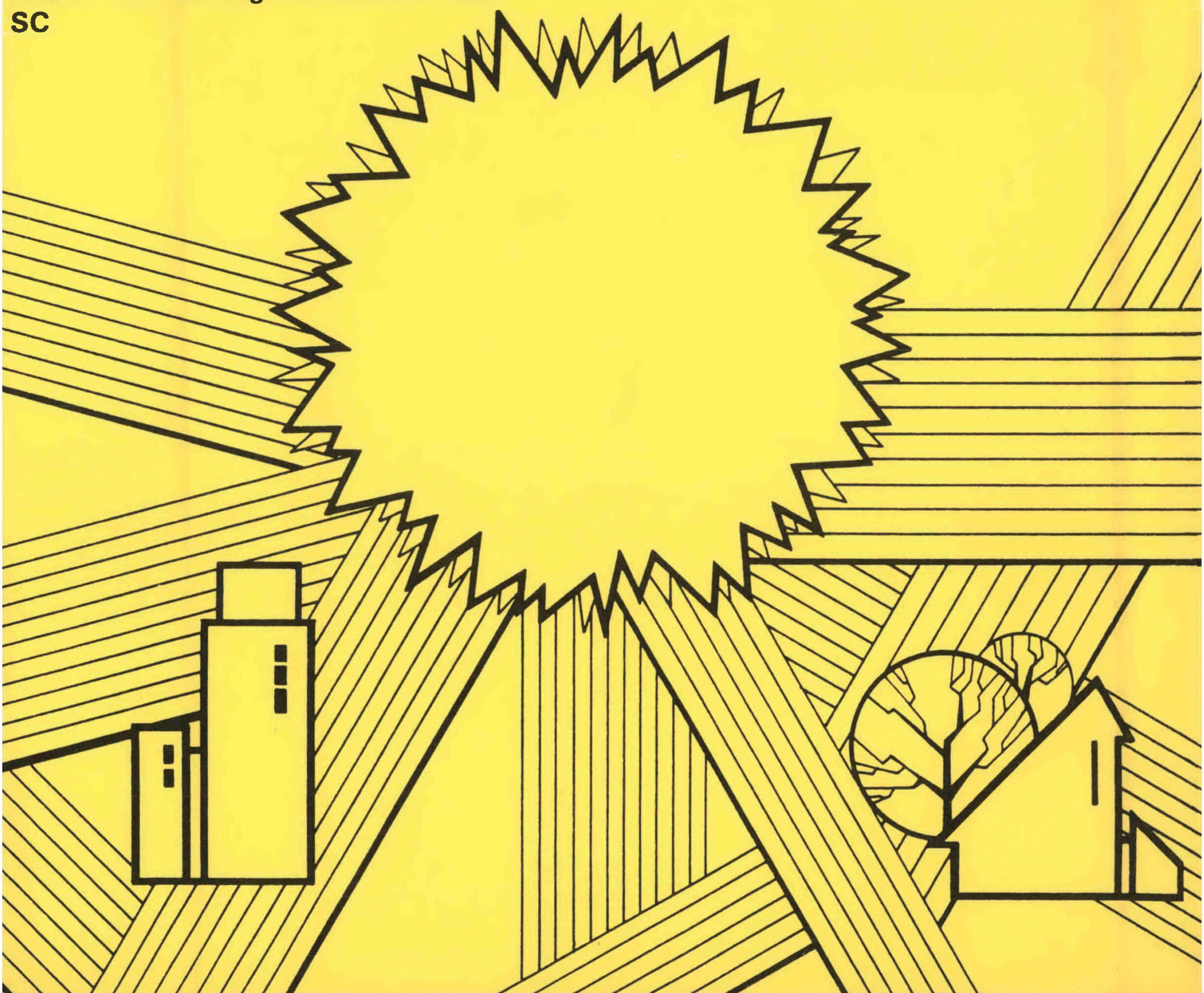
SOLAR/2074-81/14
(DE82008890)

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

MASTER

EL TORO LIBRARY

El Toro, California
March 1981 through November 1981
SC



U.S. DEPARTMENT OF ENERGY
NATIONAL SOLAR DATA PROGRAM

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EL TORO LIBRARY

EL TORO, CALIFORNIA

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

MARCH 1981 THROUGH NOVEMBER 1981

Prepared by Pekka A. Pakkala

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The National Solar Data Network
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Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

G. A. McGinnis, Project Manager

EL TORO LIBRARY

The El Toro Library is a public library facility located in El Toro, California. The active solar energy system is designed to supply the following:

Annual Design Factors
(Million BTU)

	Total Load	Solar Contribution	% Solar
Heating	135	131	97
Cooling	281	169	60

It is equipped with:

Collector: 1,427 square feet of TC-100 evacuated tube collectors manufactured by General Electric.

Storage: 1,500-gallon steel storage tank manufactured by Santa Fe Tank and Heater Company.

Auxiliary: Natural-gas-fired unit (480,000 BTU output) manufactured by Ray Pak.

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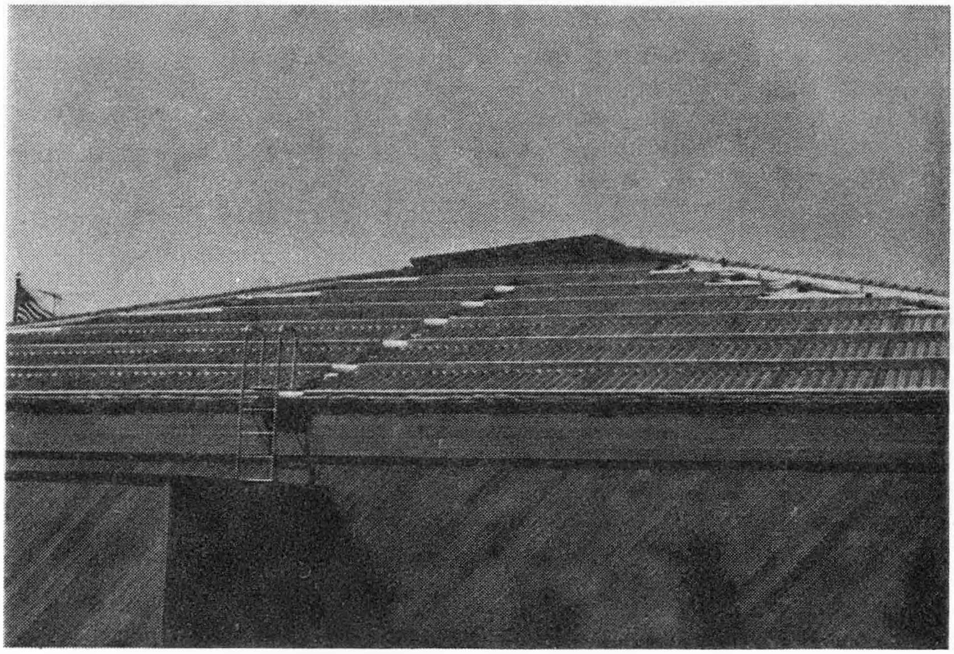
FOREWORD

This report is one of a series which describes the performance of solar energy systems in the National Solar Data Network (NSDN) for the entire heating or cooling season. Domestic hot water is also included, if there is a solar contribution. Some NSDN installations are used solely for heating domestic hot water and annual performance reports are issued for such sites. In addition, Monthly Performance Reports, prior to 1981, are available for the solar systems in the network.

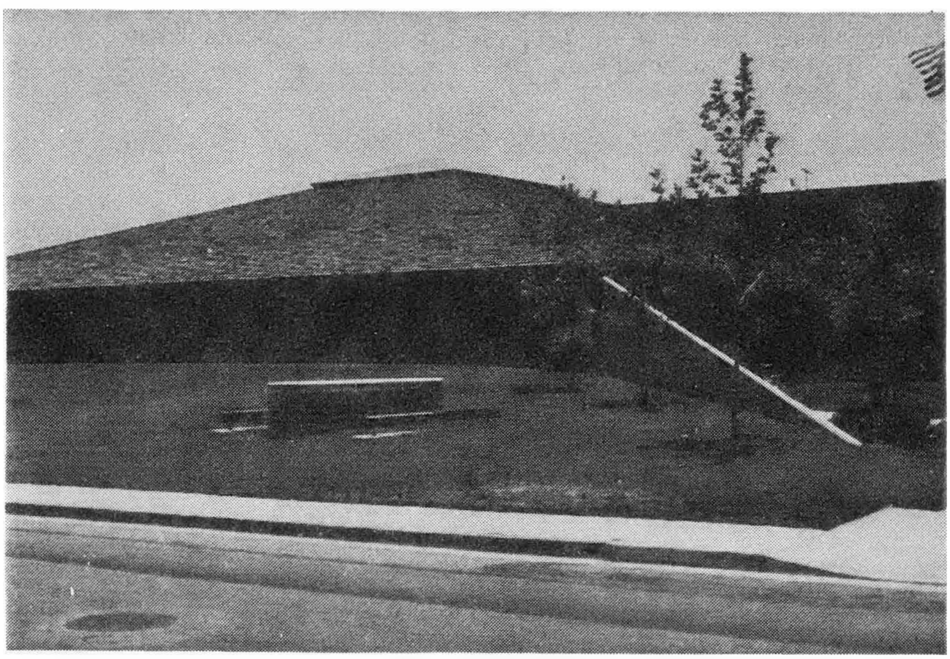
The National Solar Data Network consists of instrumented solar energy systems in buildings selected from among the 5,000 installations built (since early 1977) as part of the National Solar Heating and Cooling Demonstration Program. The overall purpose of this program is to assist in the development of solar technologies for buildings by providing data and information on the effectiveness of specific systems, the effectiveness of particular solar technologies, and the areas of potential improvement. Vitro Laboratories Division responsibility in the NSDN, under contract with the Department of Energy, is to collect data daily from the sites, analyze the data, and disseminate information to interested users.

Buildings in the National Solar Data Network are comprised of residential, commercial and institutional structures which are geographically dispersed throughout the continental United States. The variety of solar systems installed employ "active" mechanical equipment systems or "passive" design features, or both, to supply solar energy to typical building thermal loads such as space heating, space cooling, and domestic hot water. Solar systems on some sites are used to supply commercial process heat.

The buildings in the NSDN program are instrumented to monitor thermal energy flows to the space conditioning, hot water, or process loads, from both the solar system and the auxiliary or backup system. Data collection from each site, and transmission to a central computer for processing and analysis is highly automated.



Roof-mounted Collector Array



EL TORO LIBRARY

SECTION 1

SOLAR SYSTEM PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

Solar Fraction[1]	16%
Solar Savings Ratio[2]	0.16
Conventional Fuel Savings[3]	120,231 cubic feet (1,202 therms) of natural gas at the expense of 1,162 kwh of electrical energy
System Performance Factor[4]	0.24
Solar System COP[5]	21.64

Seasonal Energy Requirements
March 1981 through November 1981
(Million BTU)

	Total Load	Solar Contribution	% Solar
Cooling	217.71	85.93	16

Environmental Data

	Measured Average	Long-Term Average[6]
Outdoor temperature	71°F	64°F
Heating degree-days (Total)	250	856
Cooling degree-days (Total)	1,690	571
Daily incident solar energy	1,695 BTU/ft^2	1,861 BTU/ft^2

1. $\text{Solar Fraction} = \dfrac{\text{Solar Component of Loads}}{\text{Total Load}} \times 100$

2. $\text{Solar Savings Ratio} = \dfrac{\text{Solar Component of Load} - \text{Solar System Operating Energy}}{\text{Total Load}}$

3. Conventional Fuel Savings = Savings in BTU x 979.4 x 10^{-6} ft^3/BTU − Electric Expense in BTU x 292.8 x 10^{-6} kwh/BTU

4. Ratio of system load to the total equivalent fossil energy expended or required to support the system load.

5. $\text{Solar System COP} = \dfrac{\text{Solar Energy Used}}{\text{Solar-Unique Operating Energy}}$

6. July values are not included to allow correlation of the summary statistics.

1.1 SUMMARY AND CONCLUSIONS

The El Toro Library solar energy system performed well below design expectations during the March 1981 through November 1981 reporting period. The solar system supplied 16% of the space cooling load but the solar system was designed to supply 60% of the space cooling load. There was no space heating load. The solar system provided a fossil fuel savings of 1,202 therms (120,231 cubic feet) of natural gas at the expense of 1,162 kwh of electrical energy. These energy savings are equivalent to $376.80, based on an actual fossil fuel rate of 37.67 cents per therm (100 cubic feet) of natural gas and 6.55 cents per kwh of electrical energy. Energy savings, good collector performance, and good transfer of solar energy to storage highlighted the positive aspects of the solar system. Solar system thermal performance is summarized in Table 1 and shown graphically in Figure 1.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

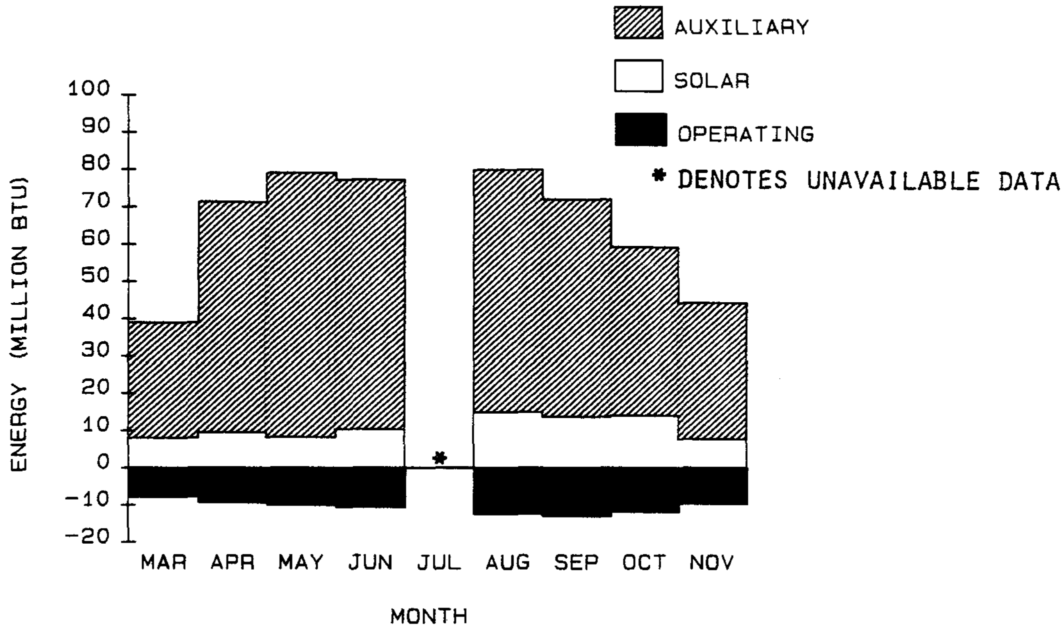
(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY		OPERATING ENERGY	ENERGY SAVINGS		SOLAR FRACTION (%)
				FOSSIL	THERMAL		FOSSIL	ELECTRICAL	
MAR	20.34	14.76	7.99 E	51.38	30.91	7.89	11.41	-0.48	20
APR	24.19	22.14	9.48 E	84.07	61.74	9.36	13.54	-0.54	13
MAY	22.83	26.64	8.14 E	96.29	70.89	10.03	11.63	-0.59	10
JUN	23.38	30.56	10.29 E	93.11	66.88	10.59	14.70	-0.59	13
JUL	*	*	*	*	*	*	*	*	*
AUG	20.58	34.91	14.84 E	91.88	65.07	12.42	21.20	-0.49	19
SEP	24.13	39.96	13.60	84.72	58.26	13.03	19.43	-0.50	20
OCT	20.24	28.18	13.94	68.39	45.20	11.85	19.92	-0.43	24
NOV	13.34	20.56	7.65	55.19	36.55	9.68	10.93	-0.35	16
TOTAL	169.03	217.71	85.93	625.03	435.50	84.85	122.76	-3.97	-
AVERAGE	21.13	27.21	10.74	78.13	54.44	10.61	15.35	-0.50	16(1)

E Denotes estimated value.
* Denotes unavailable data.
(1) Weighted average.

A major control problem with valve V8 severely reduced the expected solar contribution to the load. Other problems include nonoptimum collection control, low absorption chiller coefficient of performance (COP) during part of the reporting period, and small collector area compared to chiller capacity.

Control valve V8 permits the transfer of solar energy from the storage tank to the load subsystems. (Refer to Appendix A.) The sensor which controls the operation of valve V8 was installed incorrectly and thus prevented the utilization of solar energy when it was available. A total of 155.98 million BTU was delivered to the solar storage tank and only 85.93 million BTU were used for the



OPERATING ENERGY FOR THE SYSTEM IS CONSIDERED A SYSTEM PENALTY AND IS PLOTTED AS A NEGATIVE VALUE BELOW THE ORIGIN.

Figure 1. System Thermal Performance
El Toro Library
March 1981 through November 1981

loads. This represents only 55% utilization of energy delivered to storage. Improper operation of valve V8 reduced system performance by an estimated 54% or, conversely, the solar fraction could have been improved to 26% had this valve worked better.

The collector control was at times operating the collector pump too early in the morning and too late in the afternoon. This caused energy to be rejected from the collectors and consumed additional operating energy. The collector control at El Toro Library attempts to simulate a solar collector by measuring the temperature difference between a black and white body. An adjustable temperature differential device is programmed to operate the collector pump. However, the control differential was set slightly low and caused energy to be lost by the collector subsystem. A total of 2.64 million BTU was lost to the ambient which represents a loss of two percent. This control problem reduced the collector performance very slightly.

The absorption chiller at El Toro Library had a low efficiency, approximately 0.36, before August 1981. Maintenance was performed two times in an attempt to increase the chiller efficiency or coefficient of performance (COP). During the second visit on August 27, the chiller COP increased substantially to a value of 0.64 on August 28 and 29. Since that time, the COP has remained high at an average of 0.49. The low COP requires the consumption of more energy per unit output of chilled water. If the chiller COP had remained at an average of 0.50 from March through August, 26% less input energy would have been used.

It appears that the collector area is not large enough compared to the cooling load, thus reducing the performance below the design cooling solar fraction of

60%. A quick calculation to verify this follows. Using the energy available to storage, which is 155.98 million BTU, and assuming a 15% storage loss for an outdoor tank, yields a potential of 132.58 million BTU to satisfy the space cooling load. Assuming an absorption chiller COP of 0.65 (same as design COP) yields a solar cooling load of 86.18 million BTU. At best, the solar system could only provide 40% of the space cooling needs.

The solar energy used from March 1981 through August 1981 was calculated by a thermodynamic energy balance in the software program. This calculated value was needed because the original flow meter W201 was installed in the wrong pipe. The calculated value is believed to be very good since it compares very well with actual measurements of instrumentation installed on September 2, 1981. The actual comparison during September, October, and November months shows a nine percent deviation. The solar energy used is noted by an "E" (estimated value) as shown in Table 1. Other performance factors based upon this calculation are energy from storage, solar energy directly to loads, and solar energy used for space cooling.

The graphical representation of the system thermal performance depicted in Figure 1 demonstrates the difference between solar and auxiliary energy utilized to meet the space conditioning requirements. Figure 1 clearly shows that only a small percentage of solar energy was used in comparison to auxiliary thermal energy. The system operating energy is plotted below the axis since this represents a system penalty. High operating energy is typical for an absorption cooling system.

The flow of solar energy through the El Toro Library is presented in Figure 2. The Energy Flow Diagram represents the amount of energy collected, transported, lost, and consumed at each point in the system. The Energy Flow Diagram shows good solar collection and low transport losses to the storage tank. However, due to control problems with valve V8, only 55% of the energy delivered to storage was utilized for the space cooling subsystem. During the reporting period, there was no space heating load. The space cooling subsystem operated well and provided for the cooling needs of the library.

The solar energy coefficient of performance (COP) is depicted in Table 2. The COP simply provides a numerical value for the relationship of solar energy used or collected and the amount of conventional electrical energy required to collect or deliver it. The greater the COP value, the more efficient the process. During the reporting period, the overall solar energy system provided a weighted seasonal average COP value of 21.64. The collector subsystem functioned at a COP of 42.58. These COPs are quite good and indicate an efficient energy delivery system. These good COPs are partly due to the fact that the solar storage tank is connected in series so there is no solar-unique operating energy for the space heating and cooling subsystems. The solar-unique operating energy is depicted in Table 3.

The collector subsystem at El Toro Library performed very well during the reporting period. The collector array absorbed 169.03 million BTU of solar energy with a seasonal operational efficiency of 31%. (Refer to Table 4.) This efficiency is very good for an evacuated tube type collector since they tend to operate at high collector inlet temperatures. A total of 4.38 million BTU of energy was rejected to prevent the collector subsystem from overheating. The energy delivered to storage was 155.98 million or 92% of the collected energy. Therefore, transport losses from collector to the storage tank were very low.

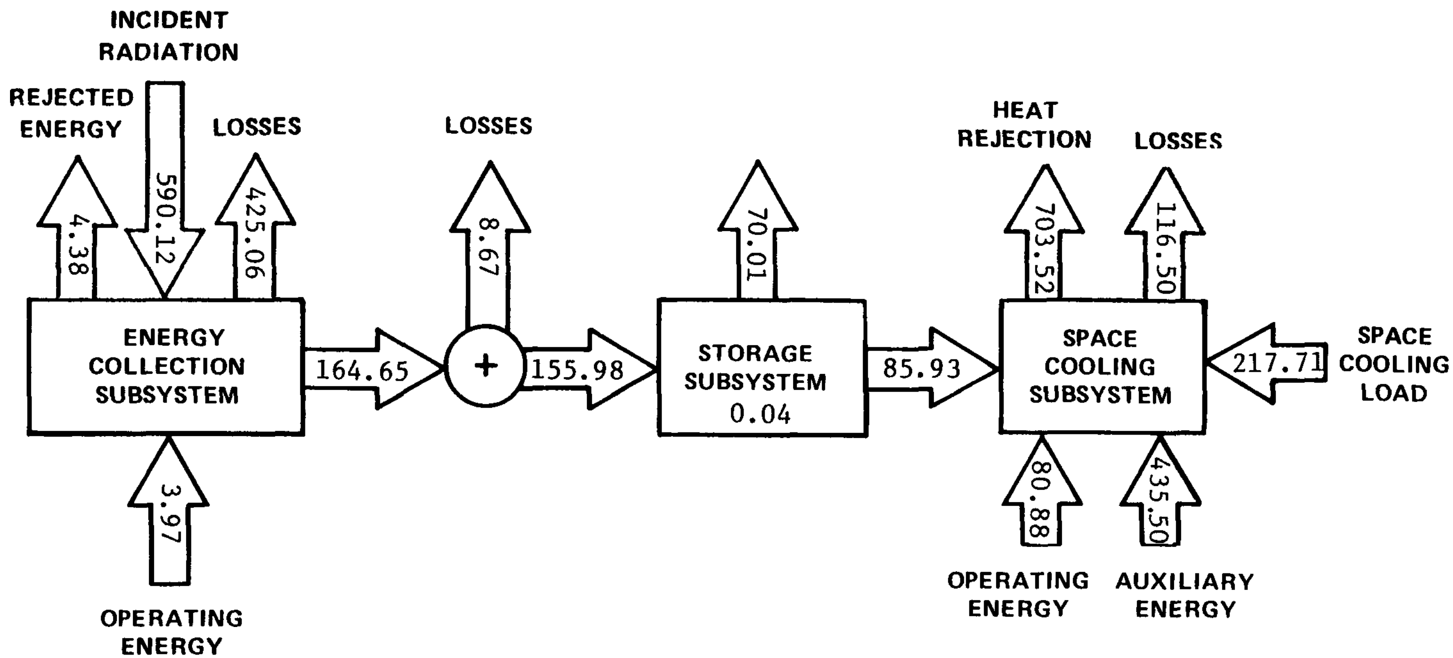


Figure 2. Energy Flow Diagram for El Toro Library
March 1981 through November 1981
(Figures in million BTU)

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM
MAR	16.65	42.38
APR	17.56	44.80
MAY	13.80	38.69
JUN	17.44	39.63
JUL	*	*
AUG	30.29	42.00
SEP	27.20	48.26
OCT	32.42	47.07
NOV	21.86	38.11
WEIGHTED AVERAGE	21.64	42.58

*Denotes unavailable data.

Table 3. SOLAR-UNIQUE OPERATING ENERGY

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	TOTAL SOLAR OPERATING ENERGY
MAR	0.48	0.48
APR	0.54	0.54
MAY	0.59	0.59
JUN	0.59	0.59
JUL	*	*
AUG	0.49	0.49
SEP	0.50	0.50
OCT	0.43	0.43
NOV	0.35	0.35
TOTAL	3.97	3.97
AVERAGE	0.50	0.50

* Denotes unavailable data.

Table 4. COLLECTOR SUBSYSTEM PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	COLLECTED SOLAR ENERGY	COLLECTOR SUBSYSTEM EFFICIENCY (%)	OPERATIONAL INCIDENT ENERGY	COLLECTOR ARRAY OPERATIONAL EFFICIENCY (%)	ECSS REJECTED ENERGY	ECSS OPERATING ENERGY	SOLAR ENERGY TO LOADS	SOLAR ENERGY TO STORAGE	DAYTIME AMBIENT TEMPERATURE (°F)
MAR	67.31	20.34	30	63.29	32	0.00	0.48	7.99 E	18.61	71
APR	76.58	24.19	32	74.03	33	0.92	0.54	9.48 E	21.67	74
MAY	76.43	22.83	30	72.21	32	1.43	0.59	8.14 E	19.95	75
JUN	89.80	23.38	26	80.20	29	1.13	0.59	10.29 E	20.93	87
JUL	*	*	*	*	*	*	*	*	*	*
AUG	88.44	20.58	23	73.48	28	0.33	0.49	14.84 E	20.86	91
SEP	77.59	24.13	31	71.90	34	0.53	0.50	13.60	22.13	86
OCT	63.95	20.24	32	61.72	33	0.04	0.43	13.94	19.10	76
NOV	50.02	13.34	27	46.92	28	0.00	0.35	7.65	12.73	73
TOTAL	590.12	169.03	-	543.75	-	4.38	3.97	85.93	155.98	-
AVERAGE	73.77	21.13	29(1)	67.97	31(1)	0.55	0.50	10.74	19.50	79

E Denotes estimated value.
* Denotes unavailable data.
(1) Weighted average.

The energy delivered to the storage tank was 155.98 million BTU, but the energy removed from storage to the loads was only 85.93 million BTU, or 55% of the energy to storage. (Refer to Table 5.) Due to control problems with valve V8, the storage performance appears poor. Also, the storage tank is located outdoors which would result in higher losses, but the tank is very well insulated. If valve V8 had operated properly, the storage performance would have been much better since system operation occurs mainly during the day.

The space cooling load of 217.71 million BTU was satisfied by 85.93 million BTU of solar energy and 435.50 million BTU of auxiliary thermal energy. The space cooling solar fraction was 16%. (Refer to Table 6.) The solar contribution provided a fossil fuel energy savings of 122.76 million BTU. The space cooling subsystem used 80.88 million BTU of operating energy to maintain the space cooling operation. As previously mentioned, the improper operation of valve V8 severely lowered the solar contribution to the space cooling load.

The space cooling load is provided by a 25-ton ARKLA WFB-300 absorption chiller. Absorption chiller performance is summarized in Table 7. The seasonal weighted average COP was 0.43. However, from March 1981 through August 27, 1981, the absorption chiller experienced a low COP. On August 27, an ARKLA repairman corrected the chiller operation and the chiller performance increased substantially. The energy input to the chiller was 503.48 million BTU while providing 217.71 million BTU of space cooling. The absorption chiller consumed 54.31 million BTU of operating energy and rejected 703.52 million BTU to the atmosphere, through the cooling tower. Overall, the chiller performance was good, but could be improved.

Table 5. STORAGE PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMPERATURE (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/hr°F)	LOSS FROM STORAGE
MAR	18.61	7.99 E	-0.04	43	167	0.65	10.66
APR	21.67	9.48 E	0.18	45	176	0.62	12.01
MAY	19.95	8.14 E	0.71	44	178	0.55	11.10
JUN	20.93	10.29 E	-0.63	46	177	0.73	11.27
JUL	*	*	*	*	*	*	*
AUG	20.86	14.84 E	-0.29	70	175	0.35	6.31
SEP	22.13	13.60	0.03	62	171	0.49	8.50
OCT	19.10	13.94	-0.03	73	159	0.29	5.19
NOV	12.73	7.65	0.11	61	158	0.26	4.97
TOTAL	155.98	85.93	0.04	-	-	*	70.01
AVERAGE	19.50	10.74	0.01	55(1)	170	0.49	8.75

E Denotes estimated value.
* Denotes unavailable data.
(1) Weighted average.

Table 6. SPACE COOLING SUBSYSTEM

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

(All values in million BTU, unless otherwise indicated)

MONTH	COOLING LOAD	SOLAR FRACTION OF LOAD	SOLAR ENERGY USED	OPERATING ENERGY	AUX THERMAL USED	AUX FOSSIL FUEL	FOSSIL ENERGY SAVINGS	BUILDING TEMP (°F)
MAR	14.76	21	7.99 E	7.41	30.91	51.38	11.41	72
APR	22.14	13	9.48 E	8.82	61.74	84.07	13.54	73
MAY	26.64	10	8.14 E	9.44	70.89	96.29	11.63	74
JUN	30.56	13	10.29 E	10.00	66.88	93.11	14.70	78
JUL	*	*	*	*	*	*	*	*
AUG	34.91	19	14.84 E	11.93	65.07	91.88	21.20	79
SEP	39.96	20	13.60	12.53	58.26	84.72	19.43	76
OCT	28.18	24	13.94	11.42	45.20	68.39	19.92	75
NOV	20.56	16	7.65	9.33	36.55	55.19	10.93	72
TOTAL	217.71	-	85.93	80.88	435.50	625.03	122.76	-
AVERAGE	27.21	16(1)	10.74	10.11	54.44	78.13	15.35	75

E Denotes estimated value.
* Denotes unavailable data.
(1) Weighted average.

Table 7. ABSORPTION CHILLER PERFORMANCE

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

MONTH	EQUIPMENT LOAD	THERMAL ENERGY INPUT	OPERATING ENERGY	REJECTED ENERGY	COEFFICIENT OF PERFORMANCE
MAR	14.76	32.57	4.94	47.33 E	0.45
APR	22.14	62.83	6.03	77.53	0.35
MAY	26.64	71.04	6.65	88.58	0.37
JUN	30.56	84.01	7.43	97.92	0.36
JUL	*	*	*	*	*
AUG	34.91	75.25	7.64	114.24	0.46
SEP	39.96	79.14	8.40	115.07	0.50
OCT	28.18	56.29	7.29	92.45	0.50
NOV	20.56	42.35	5.93	70.40	0.49
TOTAL	217.71	503.48	54.31	703.52	-
AVERAGE	27.21	62.94	6.79	87.94	0.43(1)

E Denotes estimated value.
* Denotes unavailable data.
(1) Weighted average.

The solar system provided a fossil fuel energy savings of 122.76 million BTU at the expense of 3.97 million BTU of electrical energy. (Refer to Table 8.) These energy savings are equivalent to $376.80 based on actual energy expenditures from the local utilities.

Table 8. ENERGY SAVINGS

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY USED	SPACE COOLING	ECSS OPERATING ENERGY	NET ENERGY SAVINGS	
		FOSSIL FUEL	SOLAR-UNIQUE	ELECTRICAL	FOSSIL FUEL
MAR	7.99 E	11.41	0.48	-0.48	11.41
APR	9.48 E	13.54	0.54	-0.54	13.54
MAY	8.14 E	11.63	0.59	-0.59	11.63
JUN	10.29 E	14.70	0.59	-0.59	14.70
JUL	*	*	*	*	*
AUG	14.84 E	21.20	0.49	-0.49	21.20
SEP	13.60	19.43	0.50	-0.50	19.43
OCT	13.94	19.92	0.43	-0.43	19.92
NOV	7.65	10.93	0.35	-0.35	10.93
TOTAL	85.93	122.76	3.97	-3.97	122.76
AVERAGE	10.74	15.35	0.50	-0.50	15.35

E Denotes estimated value.
* Denotes unavailable data.

Summary weather conditions at El Toro Library are presented in Table 9. The long-term weather data insolation of 1,861 BTU per square foot per day was greater than the actual insolation data of 1,695 BTU per square foot per day. This may be due to the long periods of cloudiness experienced during the year. The average ambient temperature was 71°F as compared to the long-term average of 64°F. The higher average ambient temperature is reflected in more cooling degree-days and fewer heating degree-days.

TABLE 9. WEATHER CONDITIONS

EL TORO LIBRARY
MARCH 1981 THROUGH NOVEMBER 1981

	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT^2-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
MONTH	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
MAR	1,522	1,802	63	56	96	279	28	0
APR	1,789	1,993	67	59	45	177	100	9
MAY	1,728	2,024	69	63	2	94	138	29
JUN	2,098	2,090	78	66	0	38	394	77
JUL	*	2,274	*	71	*	0	*	181
AUG	1,999	2,178	82	72	0	0	519	209
SEP	1,812	1,881	77	70	0	9	373	165
OCT	1,446	1,602	67	65	33	64	96	70
NOV	1,168	1,316	64	59	74	195	42	12
TOTAL	-	-	-	-	250	856	1,690	(571) 752
AVERAGE	1,695	(1,861) 1,907	71	(64) 65	31	95	211	84

* Denotes unavailable data.
(1) Values in parentheses do not include July long-term data to allow correlation of the summary statistics.

1.2 SYSTEM OPERATION

1.2.1 Typical System Operation

September 10, 1981 represents a sunny day of solar system operation. The variation of key system parameters for this day is presented in Figures 3a, 3b, and 3c.

Figure 3a shows the available solar radiation upon the collector array. The curve represents a clear day with high insolation levels. The highest insolation level was 287 BTU/ft^2-hr, which occurred at 1157 hours. The collector loop operating period is labeled in the figure.

Figure 3b depicts the collector array inlet and outlet temperatures during the day. The collector pump was activated at 0818 hours, at which time the collector inlet temperature was higher than the collector outlet temperature. This temperature differential occurred for only five minutes until the hot collector fluid reached the outlet temperature probe. Since the collector outlet temperature is

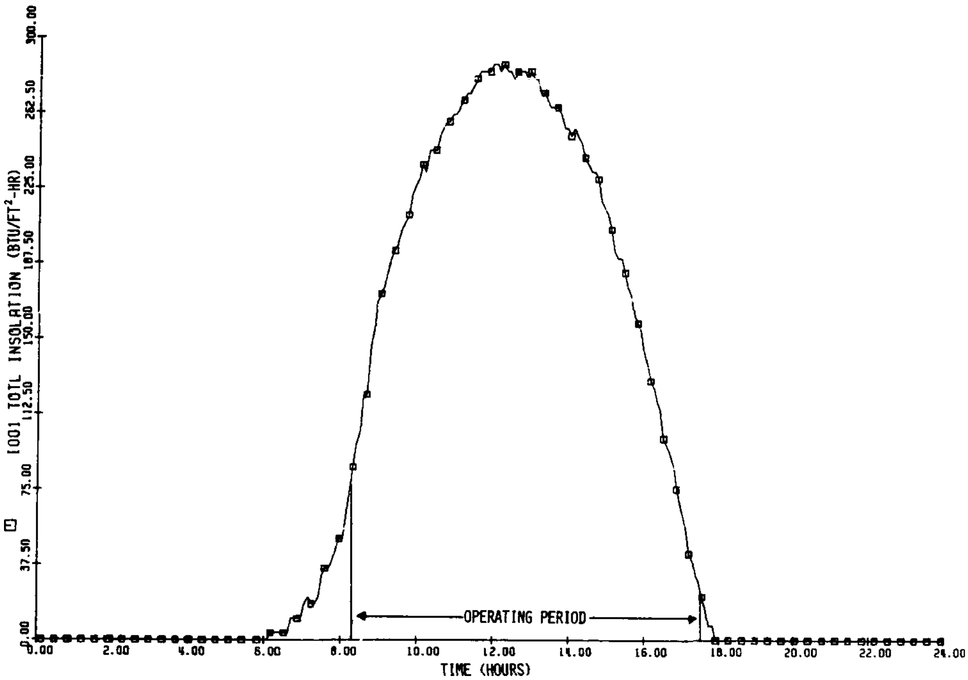


Figure 3a. Typical Insolation Data
El Toro Library
September 10, 1981

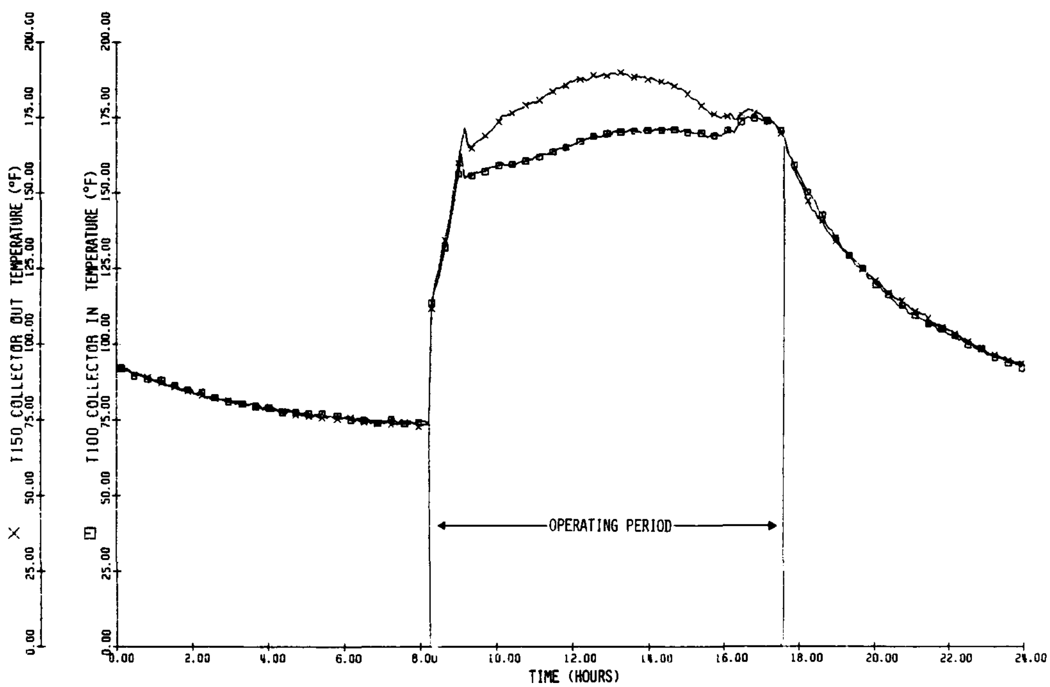


Figure 3b. Typical Collector Array Temperatures, Inlet/Outlet
El Toro Library
September 10, 1981

lower than the storage temperature, valve V5-11 allows all collector flow to bypass the storage tank. The temperature differential between collector inlet and outlet temperatures was very small until 0911 hours, when the collector flow was diverted to the storage tank. The collector inlet and outlet temperatures show a very consistent gradient resulting in good collector performance. Towards the end of the day, the temperature differential declines as the amount of insolation declines. At 1711 hours, the collector flow again bypasses the storage tank because the collector outlet falls below the storage tank temperature. The collector pump is deactivated at 1733 hours when insolation levels are too low for positive energy collection. The collector control device was not set properly, which resulted in some negative collected energy at the beginning and end of the day.

The storage tank temperature profile is presented in Figure 3c. From midnight to 0538 hours, the storage tank exhibits some tank stratification between the top and bottom of the tank. A small decrease in temperature is noted, since the storage tank is located outside. At 0538 hours, a small quantity of energy is removed from storage to the load subsystem. This removal causes a drop in the storage tank temperature. At 0855 hours, energy is again used for the loads and continues until 1400 hours. However, at 0911 hours, energy is added to storage from the collector loop and the storage tank temperatures rise until approximately 1530 hours. Between 1530 and 1730 hours, energy is added to storage. However, the top tank temperature drops a few degrees and stabilizes with the bottom tank temperature until 1914 hours. From 1914 through 2400 hours, the temperatures stratify as some energy is lost to the outside ambient.

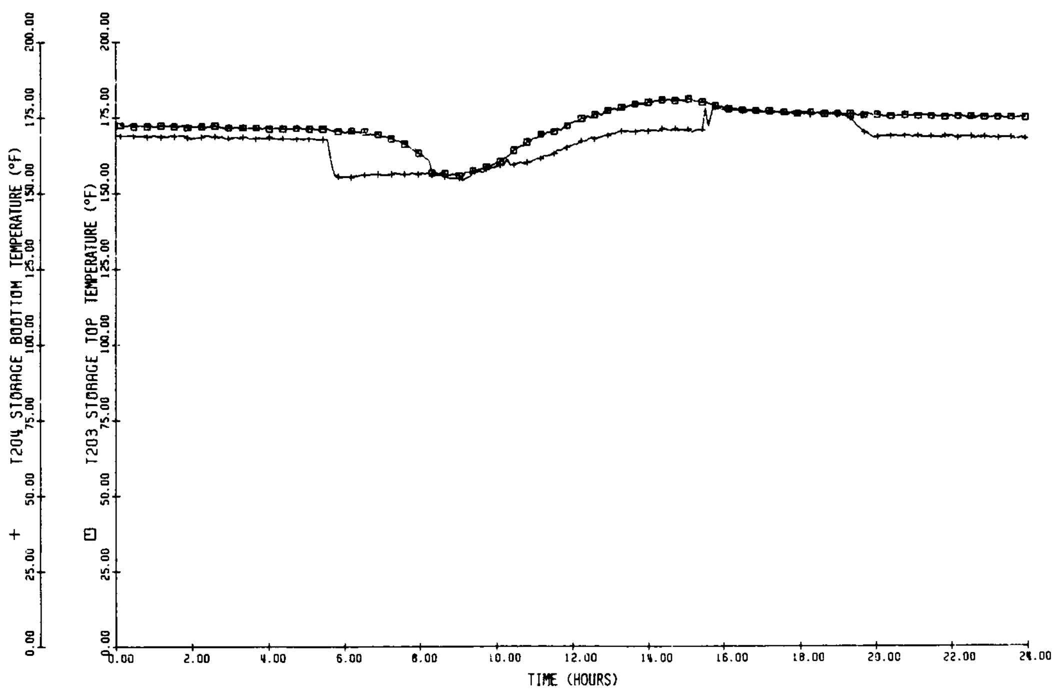


Figure 3c. Typical Storage Fluid Temperatures
El Toro Library
September 10, 1981

1.2.2 System Operating Sequence

Figure 4 presents a bar chart depicting typical system operating sequence for September 10, 1981. This data correlates with the curves presented in Figures 3a, 3b, and 3c and provides some additional insight into those curves.

There are a few observations to be made from Figure 4. First, the space cooling subsystem is activated by time clocks which correspond to building occupancy. Secondly, the energy from storage cannot supply all the space cooling energy requirements, so the auxiliary equipment is always operational until the time clocks are deactivated. Finally, the storage to space cooling load is very sporadic at times due to the control problem with valve V8. Also, valve V8 is a modulating valve which can add small quantities of solar energy from storage to the loads.

It should be noted that the time reference on these figures is "Pacific Standard Time" while the actual time was "Pacific Daylight Savings Time." In order to obtain actual operating hours, one hour should be added to all the figures.

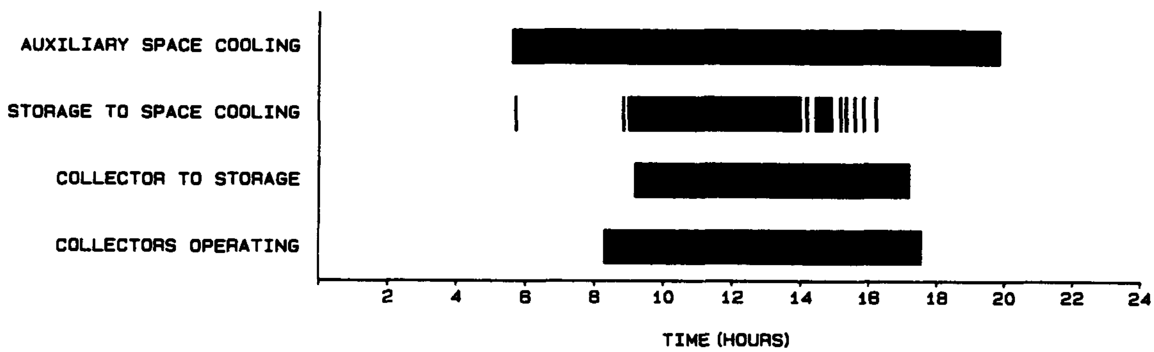


Figure 4. Typical System Operating Sequence
El Toro Library
September 10, 1981

1.3 SOLAR ENERGY UTILIZATION

The utilization of solar energy and the percentage of losses are shown in Figure 5. Figure 5 demonstrates very little difference between available and operational solar radiation, higher than expected collector losses, small transport losses to storage, and high storage losses.

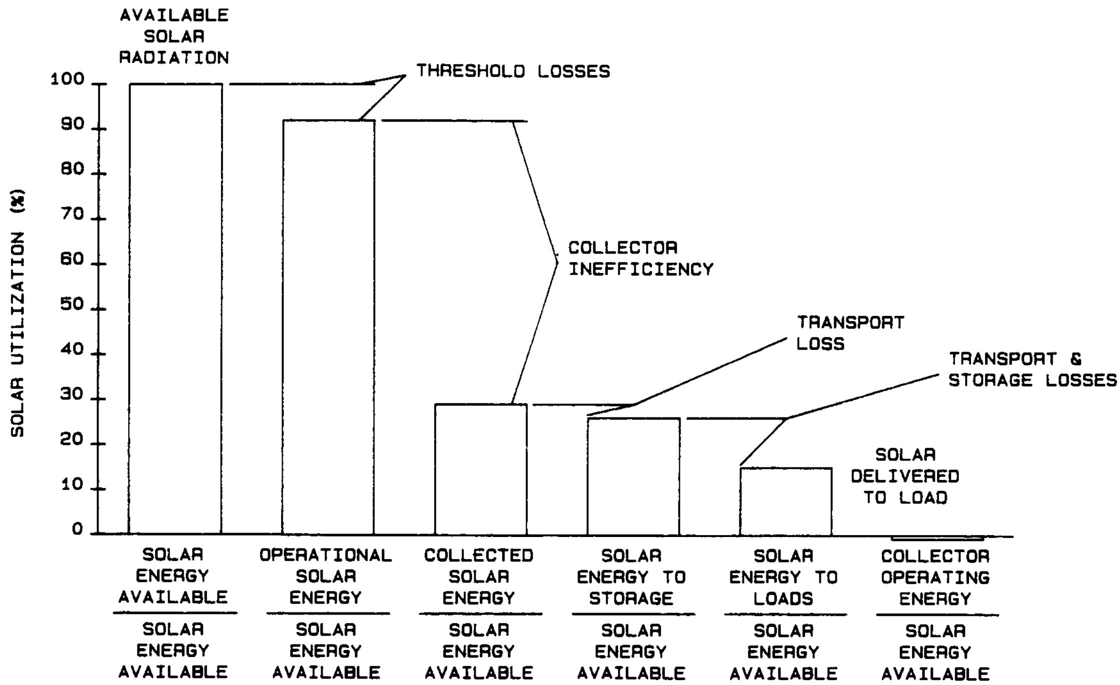


Figure 5. Solar Energy Use
El Toro Library
March 1981 through November 1981

The collector pump controller attempts to operate similarly to a pyranometer by measuring the temperature difference between a black and white body. However, the controller set point was too low and operated the collector pump during low solar radiation levels. Therefore, there is very little difference between available and operational solar radiation.

The high collector losses are a result of operating the collector pump before and after positive collection periods. Due to the low set point on the collector control, there were many times when positive solar collection could not be attained. The collector control problem increased collector losses and decreased collector efficiency.

There is only a three percent transport loss between collected solar energy and solar energy delivered to storage. The small transport loss indicates good pipe insulation and good control operation of solar energy delivered to storage.

A control problem with valve V8 resulted in high storage losses. The control sensor was installed in an incorrect position which caused improper operation of valve V8, which controls the transfer of solar energy from storage delivered to the loads. The transport and storage losses were 11%, based upon the ratio of losses to available solar radiation.

SECTION 2

REFERENCES

*1. National Solar Data Network, Department of Energy, prepared under Contract Number DE-AC01-79CS30027, Vitro Laboratories, Silver Spring, Maryland, January 1980.

2. J. T. Smok, V. S. Sohoni, J. M. Nash, "Processing of Instrumented Data for the National Solar Heating and Cooling Demonstration Program," Conference on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, D.C., April 1978.

3. E. Streed, et al, Thermal Data Requirements and Performance Evaluation Procedures for the National Heating and Cooling Demonstration Program, NBSIR-76-1137, National Bureau of Standards, Washington, D.C., 1976.

4. Mears, J. C., Reference Monthly Environmental Data for Systems in the National Solar Data Network. Department of Energy report SOLAR/0019-79/36, Washington, D.C., 1979.

5. ASHRAE Standard 93-77, Methods of Testing to Determine the Thermal Performance of Solar Collectors, The American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, NY, 1977.

**6. ASHRAE Standard 94-77, Methods of Testing Thermal Storage Devices Based on Thermal Performance, The American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, NY, 1977.

*6A. User's Guide to monthly Performance Reports, November 1981, SOLAR/0004-81/18, Vitro Laboratories, Silver Spring, Maryland.

*6B. Instrumentation Installation Guidelines March 1981, Parts 1, 2, and 3, SOLAR/0001-81/15, Vitro Laboratories, Silver Spring, Maryland.

7. Monthly Performance Report, El Toro Library, August 1981, SOLAR/2074-81/08, Vitro Laboratories, Silver Spring, Maryland.

8. Monthly Performance Report, El Toro Library, September 1981, SOLAR/2074-81/09, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, El Toro Library, October 1981, SOLAR/2074-81/10, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, El Toro Library, November 1981, SOLAR/2074-81/11, Vitro Laboratories, Silver Spring, Maryland.

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* Copies of these reports may be obtained from Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

**Note: Reference [6] only used if the heat transfer coefficient discussion in Section 5.3.1.2 applies.

APPENDIX A

SYSTEM DESCRIPTION

The El Toro Library is a one-story facility of modern design, located in El Toro, California. The building contains 10,000 square feet of floor area with very few windows, located at the building entrances. The library is functional year-round and is occupied Monday through Saturday.

The building was designed to incorporate a solar energy system on the south-facing roof. The solar energy system is interconnected to the building space heating and cooling equipment. The solar energy system was designed to provide 97% of the space heating load and 60% of the space cooling load.

The solar energy system incorporates 82 panels with a gross area of 1,427 square feet of evacuated tubular glass collectors (TC-100) manufactured by General Electric. The collectors are oriented 30° West of due South at a tilt of 19 degrees from horizontal. The collector subsystem utilizes treated city water as a transfer medium from collector to storage tank. The storage tank is a 1,500-gallon insulated steel tank which is located outside, above ground level. The storage tank provides thermal storage for the collected solar energy before delivery to the building load.

The space heating subsystem uses solar energy from storage and/or thermal energy from the natural-gas-fired boiler. The thermal energy is delivered to the air handling unit, which distributes the energy to the conditioned space.

The space cooling subsystem uses an absorption chiller to provide chilled water to the air handling unit. The generator portion of the absorption chiller unit uses hot water from solar storage and/or hot water supplied by the natural-gas-fired boiler.

The manufacturers of the major solar system equipment and components are listed below.

Equipment/Component	Manufacturer	Model No.
Evacuated tube collectors	General Electric	TC-100
Heat Rejector	Young Radiator Co.	22D20
Solar Storage Tank	Sante Fe Tank & Heater Co.	18333
Gas-Fired Boiler	Ray Pak	E602-T
Absorption Chiller	ARKLA Corp.	WFB-300
Cooling Tower	Baltimore Aircoil of CA	VXT-45C
Air Handling Unit (AHU)	Air Dynamics, Inc.	MTW-90
Pumps P1, P2, P3, P4, P5	Frederick Pump Engineering	
3-Way Valves V3, V4, V5-11, V8, V12, V13	Barber Colman	
Expansion Tanks	Wood Inc. Products	

The system, shown schematically in Figure A-1, has nine modes of operation.

Mode 1 - Solar Energy Collection - Solar energy collection occurs when insolation levels are sufficient (as controlled by a Barber Colman comparator). When the insolation levels exceed the predetermined set point, collector pump P1 or P2 will activate flow for solar energy collection. This mode behaves like a collector loop warm-up method, since all the flow bypasses the storage tank. Pump P1 or P2 will deactivate when insolation levels fall below the set point.

Mode 2 - Collector-to-Storage Flow - Solar energy is delivered to the storage tank when the collector outlet temperature exceeds the temperature in the storage tank. Three-way control valve V5-11 will change position to allow full flow into the storage tank. When the collector outlet temperature falls below the storage tank temperature, valve V5-11 will reverse its position and flow will again bypass the storage tank. (Collector pump P1 or P2 must be operating.) Valve V5-11 has complete control of this mode.

Mode 3 - Solar Storage-to-Space Heating/Cooling Load - This mode occurs when there is a cooling or heating demand and the storage tank temperature is greater than the load loop return temperature. Control valve V8 will allow flow from the load loop return into storage and provide solar heated water to the loads. Valve V8 will continue to deliver stored energy until the load loop return temperature exceeds the storage temperature. Valve V8 will then change position and all flow will bypass the storage tank. Valve V8 has complete control of solar energy delivered to the loads.

Mode 4 - Auxiliary Energy for Heating/Cooling - When the boiler set point is greater than the storage tank temperature, then the auxiliary natural-gas-fired boiler will turn on to meet the energy needs of the building. The boiler will provide energy for the space heating coils or to the generator inlet of the absorption chiller.

Mode 5 - Solar Energy Heat Rejection - This mode will activate when the storage tank temperature exceeds 210°F. Control valve V3 will allow flow to the heat rejector and the fan will dissipate excess collected energy to the environment. The heat rejection mode is for equipment protection from high temperatures.

Mode 6 - Freeze Protection - Stage 1 - This mode will activate collector pump P1 or P2 when the ambient temperature falls below 38°F. All the collector flow will bypass storage and this is the first stage of freeze protection.

Mode 7 - Freeze Protection - Stage 2 - This second stage of freeze protection follows the first stage of freeze protection. The second stage will allow modulation valve V5-11 to use stored energy into the collector loop.

Mode 8 - Freeze Protection - Stage 3 - The third stage of freeze protection will allow flow of city water to the collector loop when the collector outlet temperature falls below 35°F. Valves V1 and V2 will purge city water and discharge flushing water to drain.

Mode 9 - Collector Over-Temperature - If the collector array experiences temperatures greater than 320°F, then the control sensor will lock out solar pumps P1 and P2 and retain valves V1 and V2 in their closed position. This will prevent thermal shock in the collector array.

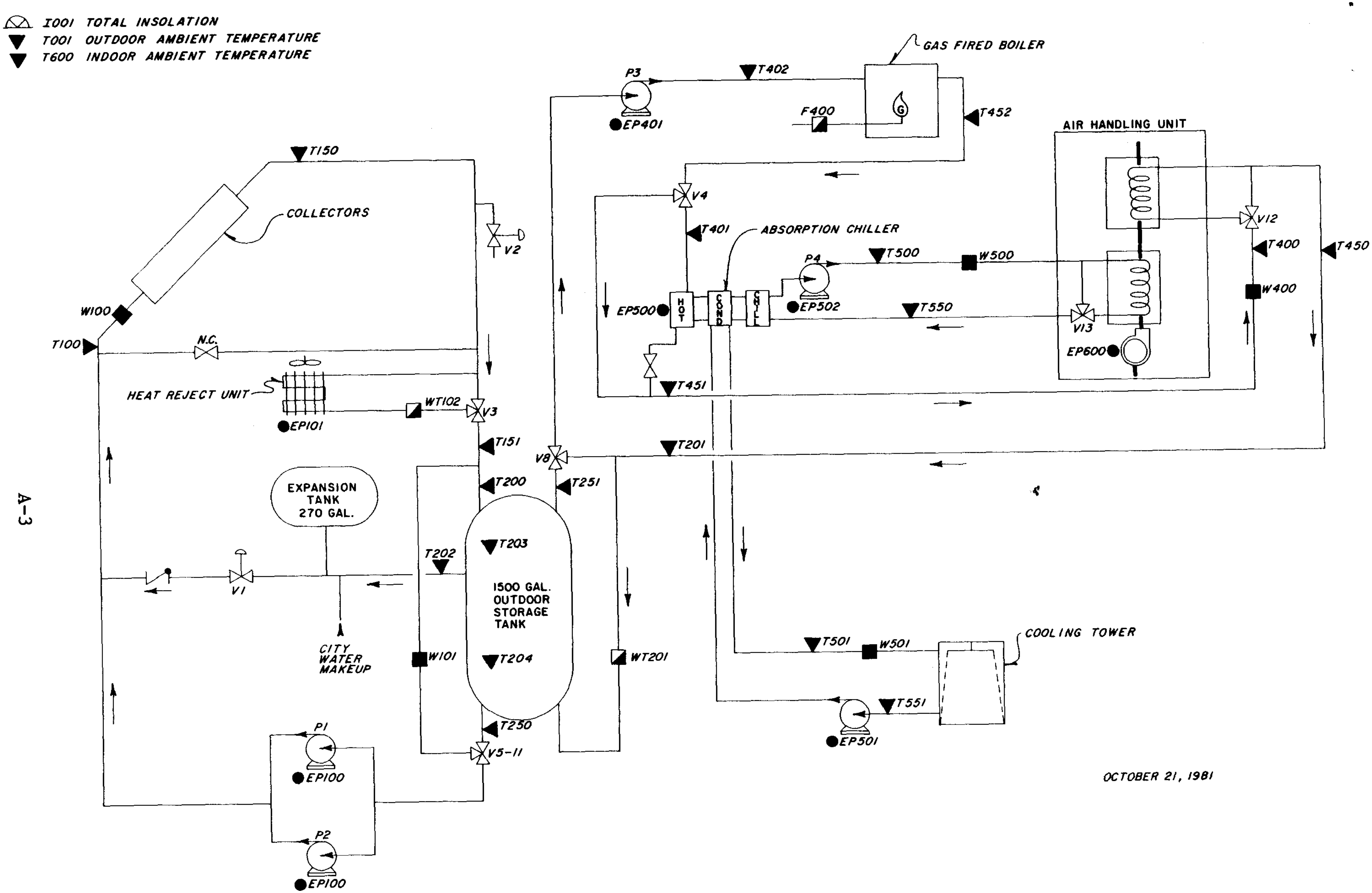

Figure A-1. El Toro Library Solar Energy System Schematic

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

The performance of the El Toro Library solar energy system is evaluated by calculating a set of primary performance factors which are based on those in the intergovernmental agency report Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program (NBSIR-76/1137).

An overview of the NSDN data collection and dissemination process is shown in Figure B-1.

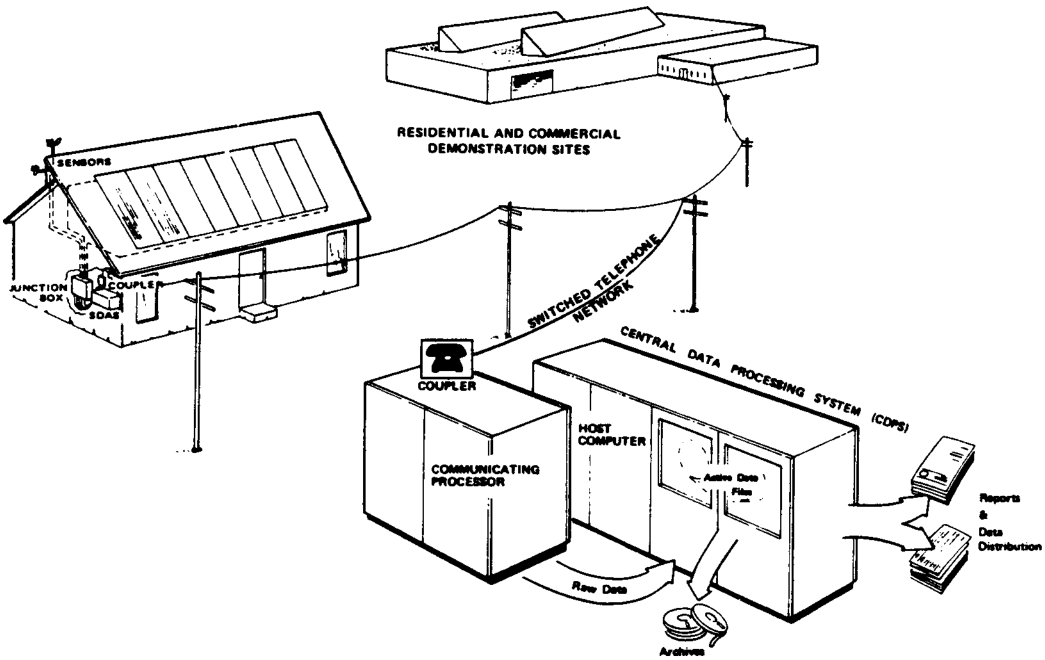

Figure B-1. The National Solar Data Network

DATA COLLECTION AND PROCESSING

Each site contains standard industrial instrumentation modified for the particular site. Sensors measure temperatures, flows, insolation, electric power, fossil fuel usage, and other parameters. These sensors are all wired into a junction box (J-box), which is in turn connected to a microprocessor data logger called the Site Data Acquisition Subsystem (SDAS). The SDAS can read up to 96 different channels, one channel for each sensor. The SDAS takes the analog voltage input to each channel and converts it to a 10-bit word. At intervals of every 320 seconds, the SDAS samples each channel and records the values on a cassette tape. Some of the channels can be sampled 10 times in each 320 second interval, and the average value is recorded in the tape.

Each SDAS is connected through a modem to voice-grade telephone lines which are used to transmit the data to a central computer facility. This facility is the Central Data Processing System (CDPS), located at Vitro Laboratories in Silver Spring, Maryland. The CDPS hardware consists of an IBM System 7, an IBM 370/145, and an IBM 3033. The System 7 periodically calls up each SDAS in System 7. Typically, the System 7 collects data from each SDAS six times a week, although the tape can hold three to five days of data, depending on the number of channels.

The data received by the System 7 are in the form of digital counts in the range of 0-1023. These counts are then processed by software in the CDPS, where they are converted from counts to engineering units (EU) by applying appropriate calibration constants. The engineering unit data called "detailed measurements" in the software are then tabulated on a daily basis for the site analyst. The CDPS is also capable of transforming this data into plots, graphs, and processed reports.

Solar system performance reports present system parameters as monthly values. If some of the data during the month is not collected due to solar system instrumentation system, or data acquisition problems, or if some of the collected data is invalid, then the collected valid data is extrapolated to provide the monthly performance estimates. Researchers and other users who require unextrapolated, "raw" data may obtain data by contacting Vitro Laboratories.

DATA ANALYSIS

The analyst develops a unique set of "site equations" (given in Appendix D) for each site in the NSDN, following the guidelines presented herein.

The equations calculate the flow of energy through the system, including solar energy, auxiliary energy, and losses. These equations are programmed in PL/1 and become part of the Central Data Processing System. The PL/1 program for each site is termed the site software. The site software processes the detailed data, using as input a "measurement record" containing the data for each scan interval. The site software produces as output a set of performance factors, on an hourly, daily, and monthly basis.

These performance factors (Appendix C) quantify the thermal performance of the system by computing energy flows throughout the various subsystems. The system performance may then be evaluated based on the efficiency of the system in transferring these energies.

Performance factors which are considered to be of primary importance are those which are essential for system evaluation. Without these primary performance factors (which are denoted by an asterisk in Appendix C), comparative evaluation of the wide variety of solar energy systems would be impossible. An example of a primary performance factor is SECA - Solar Energy Collected by the Array. This is quite obviously a key parameter in system analysis.

Secondary performance factors are data deemed important and useful in comparison and evaluation of solar systems, particularly with respect to component interactions and simulation. In most cases these secondary performance factors are computed as functions of primary performance factors.

There are irregularly occurring cases of missing data as is normal for any real time data collection from mechanical equipment. When data for individual scans or whole hours are missing, values of performance factors are assigned which are interpolated from measured data. If no valid measured data are available for interpolation, a zero value is assigned. If data are missing for a whole day, each hour is interpolated separately. Data are interpolated in order to provide solar system performance factors on a whole hour, whole day and whole month basis for use by architects and designers.

REPORTING

The performance of the El Toro Library solar energy system from March 1981 through November 1981 was analyzed during the year, and Monthly Performance Reports were prepared for the months when sufficient valid data were available.

In addition, data are included in this report which are not in Monthly Performance Reports.

OTHER DATA REPORTS ON THIS SITE

Monthly Performance Reports:

August 1981, SOLAR/2074-81/08
September 1981, SOLAR/2074-81/09
October 1981, SOLAR/2074-81/10
November 1981, SOLAR/2074-81/11

APPENDIX C

PERFORMANCE FACTORS AND SOLAR TERMS

The performance factors identified in the site equations (Appendix D) by the use of acronyms or symbols are defined in this Appendix in Section 1. Section 1 includes the acronym, the actual name of the performance factor, and a short definition.

Section 2 contains a glossary of solar terminology, in alphabetical order. These terms are included for quick reference by the reader.

Section 3 describes general acronyms used in this report.

SECTION 1. PERFORMANCE FACTOR DEFINITIONS AND ACRONYMS

ACRONYM	NAME	DEFINITION
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 Subsystems	Thermal energy delivered to all load subsystems to support a portion of the subsystem loads, from all auxiliary sources.
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.
CAT	SCS Auxiliary Thermal Energy	Amount of energy provided to the SCS by a BTU heat transfer fluid from an auxiliary source.
* 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.
COPE	SCS Operating Energy	Amount of energy required to support the SCS operation which is not intended to be applied directly to the SCS load.
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.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
CSE	Solar Energy to SCS	Amount of solar energy delivered to the SCS.
CSEO	Energy Delivered from ECSS to Load Subsystems	Amount of energy supplied from the ECSS to the load subsystems (including any auxiliary energy supplied to the ECSS).
* CSFR	SCS Solar Fraction	Portion of the SCS load which is supported by solar energy.
CSOPE	ECSS Operating Energy	Amount of energy used to support the ECSS operation (which is not intended to be supplied to the ECSS thermal state).
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 demonstration SCS, for identical SCS loads.
* 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 demonstration SCS, for identical loads.
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 energy provided to the SHS by a heat transfer fluid from an auxiliary source.
* HL	Space Heating Subsystem Load	Energy required to satisfy the temperature control demands of the space heating subsystem.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
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).
HOURCT	Record Time	Count of hours elapsed from the start of 1977.
* HSFR	SHS Solar Fraction	Portion of the SHS load which is supported by solar energy.
HSE	Solar Energy to SHS	Amount of solar energy delivered to the SHS.
* 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 demonstration 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 demonstration 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 Consumption	Amount of heated water delivered to the load from the hot water subsystem.
* HWL	Hot Water Subsystem Load	Amount of energy supplied to the HWS.
* HWDM	Hot Water Demand	Energy required to satisfy the temperature control demands of the building service hot water system.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
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.
HWSE	Solar Energy to HWS	Amount of solar energy delivered to the HWS.
* HWSFR	HWS Solar Fraction	Portion 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 demonstration 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 demonstration HWS, for identical loads.
RELH	Relative Humidity	Average outdoor relative humidity at the site.
* SE	Incident Solar Energy	Amount of solar energy incident upon one square foot of the collector plane.
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.
SECA	Collected Solar Energy by Array	Amount of thermal energy added to the heat transfer fluid by the collector array.
SEDF	Diffuse Insolation	Amount of diffuse solar energy incident upon one square foot of a collector plane.
SEOP	Operational Incident Solar Energy	Amount of incident solar energy upon the collector array whenever the collector loop is active.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
* SEL	Solar Energy to Load Subsystems	Amount of solar energy supplied by the ECSS to all load subsystems.
* SFR	Solar Fraction of System Load	Portion of the system load which was supported by solar energy.
STECH	Change in ECSS Stored Energy	Change in ECSS stored energy during reference 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.
* 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.
* 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.
* TB	Building Temperature	Average temperature of the controlled space of the building.
TCECOP	TCE Coefficient of Performance	Coefficient of performance of the thermodynamic conversion equipment.
TCEI	TCE Thermal Input Energy	Equivalent thermal energy which is supplied as a fuel source to thermodynamic conversion equipment.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
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 which is not intended to appear directly in the load.
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.
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.
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.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
WDIR	Wind Direction	Average wind direction at the site.
WIND	Wind Velocity	Average wind velocity at the site.

* Primary Performance Factors

SECTION 2. SOLAR TERMINOLOGY

Absorptivity	The ratio of absorbed radiation by a surface to the total incident radiated energy on that surface.
Active Solar System	A system in which a transfer fluid (liquid or air) is circulated through a solar collector where the collected energy is converted, or transferred, to energy in the medium.
Air Conditioning	Popularly defined as space cooling, more precisely, the process of treating indoor air by controlling the temperature, humidity and distribution to maintain specified comfort conditions.
Ambient Temperature	The surrounding air temperature.
Auxiliary Energy	In solar energy technology, the energy supplied to the heat or cooling load from other than the solar source, usually from a conventional heating or cooling system. Excluded are operating energy, and energy which may be supplemented in nature but does not have the auxiliary system as an origin, i.e., energy supplied to the space heating load from the external ambient environment by a heat pump. The electric energy input to a heat pump is defined as operating energy.
Auxiliary Energy Subsystem	In solar energy technology the Auxiliary Energy System is the conventional heating and/or cooling equipment used as supplemental or backup to the solar system.
Array	An assembly of a number of collector elements, or panels, into the solar collector for a solar energy system.
Backflow	Reverse flow.
Backflow Preventer	A valve or damper installed to prevent reverse flow.
Beam Radiation	Radiated energy received directly, not from scattering or reflecting sources.
Collected Solar Energy	The thermal energy added to the heat transfer fluid by the solar collector.

Collector Array Efficiency	Same as Collector Conversion Efficiency. Ratio of the collected solar energy to the incident solar energy. (See also Operational Collector Efficiency.)
Collector Subsystem	The assembly of components that absorbs incident solar energy and transfers the absorbed thermal energy to a heat transfer fluid.
Concentrating Solar Collector	A solar collector that concentrates the energy from a larger area onto an absorbing element of smaller area.
Conversion Efficiency	Ratio of thermal energy output to solar energy incident on the collector array.
Conditioned Space	The space in a building in which the air is heated or cooled to maintain a desired temperature range.
Control System or Subsystem	The assembly of electric, pneumatic, or hydraulic, sensing, and actuating devices used to control the operating equipment in a system.
Cooling Degree Days	The sum over a specified period of time of the number of degrees the average daily temperature is <u>above</u> 65°F.
Cooling Tower	A heat exchanger that transfers waste heat to outside ambient air.
Diffuse Radiation	Solar Radiation which is scattered by air molecules, dust, or water droplets and incapable of being focused.
Drain Down	An arrangement of sensors, valves and actuators to automatically drain the solar collectors and collector piping to prevent freezing in the event of cold weather.
Duct Heating Coil	A liquid-to-air heat exchanger in the duct distribution system.
Effective Heat Transfer Coefficient	The heat transfer coefficient, per unit plate area of a collector, which is a measure of the total heat losses per unit area from all sides, top, back, and edges.
Energy Gain	The thermal energy gained by the collector transfer fluid. The thermal energy output of the collector.

Energy Savings	The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.
Expansion Tank	A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as to the system heat transfer fluid expands and contracts to prevent excessive pressure from developing and causing damage.
F-Curve	The collector instantaneous efficiency curve. Used in the "F-curve" procedure for collector analysis (see Instantaneous Efficiency).
Fixed Collector	A solar collector that is fixed in position and cannot be rotated to follow the sun daily or seasonably.
Flat-Plate Collector	A solar energy collecting device consisting of a relatively thin panel of absorbing material. A container with insulated bottom and sides and covered with one or more covers transparent to visible solar energy and relatively opaque to infrared energy. Visible energy from the sun enters through the transparent cover and raises the temperature of the absorbing panel. The infrared energy re-radiated from the panel is trapped within the collector because it cannot pass through the cover. Glass is an effective cover material (see Selective Surface).
Focusing Collector	A concentrating type collector using parabolic mirrors or optical lenses to focus the energy from a large area onto a small absorbing area.
Fossil Fuel	Petroleum, coal, and natural gas derived fuels.
Glazing	In solar/energy technology, the transparent covers used to reduce energy losses from a collector panel.

Heat Exchanger	A device used to transfer energy from one heat transfer fluid to another while maintaining physical segregation of the fluids. Normally used in systems to provide an interface between two different heat transfer fluids.
Heat Transfer Fluid	The fluid circulated through a heat source (solar collector) or heat exchanger that transports the thermal energy by virtue of its temperature.
Heating Degree Days	The sum over a specified period of time of the number of degrees the average daily temperature is <u>below</u> 65°F.
Instantaneous Efficiency	The efficiency of a solar collector at one operating point, $\frac{Ti-Ta}{I}$, under steady state conditions (see Operating Point).
Instantaneous Efficiency Curve	A plot of solar collector efficiency against operating point, $\frac{Ti-Ta}{I}$ (see Operating Point).
Incidence Angle	The angle between the line to a radiating source (the sun) and a line normal to the plane of the surface being irradiated.
Incident Solar Energy	The amount of solar energy irradiating a surface taking into account the angle of incidence. The effective area receiving energy is the product of the area of the surface times the cosine of the angle of incidence.
Insolation	Incoming solar radiation.
Load	That to which energy is supplied, such as space heating load or cooling load. The system load is the total solar and auxiliary energy required to satisfy the required heating or cooling.
Manifold	The piping that distributes the transport fluid to and from the individual panels of a collector array.
Microclimate	Highly localized weather features which may differ from long term regional values due to the interaction of the local surface with the atmosphere.

Nocturnal Radiation	The loss of thermal energy by the solar collector to the night sky.
Operating Energy	The amount of energy (usually electrical energy) required to operate the solar and auxiliary equipments and to transport the thermal energy to the point of use, and which is not intended to directly affect the thermal state of the system.
Operating Point	A solar energy system has a dynamic operating range due to changes in level of insolation (I), fluid input temperature (T), and outside ambient temperature (Ta). The operating point is defined as: $\frac{Ti-Ta}{I}$ $\frac{°F \times hr. \times sq. ft.}{BTU}$
Operational Collector Efficiency	Ratio of collected solar energy to incident solar energy only during the time the collector fluid is being circulated with the intention of delivering solar-source energy to the system.
Outgassing	The emission of gas by materials and components, usually during exposure to elevated temperature, or reduced pressure.
Passive Solar System	A system which uses architectural components of the building to collect, distribute, and store solar energy.
Pebble Bed (Rock Bed)	A space filled with uniform-sized pebbles to store solar-source energy by raising the temperature of the pebbles.
Reflected Radiation	Insolation reflected from a surface, such as the ground or a reflecting element onto the solar collector.
Rejected Energy	Energy intentionally rejected, dissipated, or dumped from the solar system.
Retrofit	The addition of a solar energy system to an existing structure.
Selective Surface	A surface that has the ability to readily absorb solar radiation, but re-radiates little of it as thermal radiation.

Sensor	A device used to monitor a physical param eter in a system, such as temperature or flow rate, for the purpose of measurement or control.
Solar Conditioned Space	The area in a building that depends on solar energy to provide a fraction of the heating and cooling needs.
Solar Fraction	The fraction of the total load supplied by solar energy. The ratio of solar energy supplied to loads divided by total load. Often expressed as a percentage.
Solar Savings Ratio	The ratio of the solar energy supplied to the load minus the solar system operating energy, divided by the system load.
Storage Efficiency, N_s	Measure of effectiveness of transfer of energy through the storage subsystem taking into account system losses.
Storage Subsystem	The assembly of components used to store solar-source energy for use during periods of low insolation.
Stratification	A phenomenon that causes a distinct thermal gradient in a heat transfer fluid, in contrast to a thermally homogeneous fluid. Results in the layering of the heat transfer fluid, with each layer at a different temperature. In solar energy systems, stratification can occur in liquid storage tanks or rock beds, and may even occur in pipes and ducts. The temperature gradient or layering may occur in a horizontal, vertical or radial direction.
System Performance Factor	Ratio of system load to the total equivalent fossil energy expended or required to support the system load.
Ton of Refrigeration	The heat equivalent to the melting of one ton (2,000 pounds) of ice at 32°F in 24 hours. A ton of refrigeration will absorb 12,000 BTU/hr, or 288,000 BTU/day.
Tracking Collector	A solar collector that moves to point in the direction of the sun.
Zone	A portion of a conditioned space that is controlled to meet heating or cooling requirements separately from the other space or other zones.

SECTION 3. GENERAL ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineering.
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 Fahrenheit degree. One BTU is equivalent to 2.932×10^{-4} kwh of electrical energy.
COP	Coefficient of Performance. The ratio of total load to solar-source energy.
DHW	Domestic Hot Water.
ECSS	Energy Collection and Storage System.
HWS	Domestic or Service Hot Water Subsystem.
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.
NSDN	National Solar Data Network.
SCS	Space Cooling Subsystem.
SHS	Space Heating Subsystem.
SOLMET	Solar Radiation/Meteorology Data.

APPENDIX D

PERFORMANCE EQUATIONS

EL TORO LIBRARY

INTRODUCTION

Solar energy system performance is evaluated by performing energy balance computations on the system and its major subsystems. These calculations are based on physical measurement data taken from each sensor every 320 seconds.* This data is then mathematically combined to determine the hourly, daily, and monthly performance of the system. This appendix describes the general computational methods and the specific energy balance equations used for this site.

Data samples from the system measurements are integrated to provide discrete approximations of the continuous functions which characterize the system's dynamic behavior. This integration is performed by summation of the product of the measured rate of the appropriate performance parameters and the sampling interval over the total time period of interest.

There are several general forms of integration equations which are applied to each site. These general forms are exemplified as follows: the total solar energy available to the collector array is given by

$$\text{SOLAR ENERGY AVAILABLE} = (1/60)\ \Sigma\ [\text{I001} \times \text{CLAREA}] \times \Delta\tau$$

where I001 is the solar radiation measurement provided by the pyranometer in BTU per square foot per hour, CLAREA is the area of the collector array in square feet, $\Delta\tau$ is the sampling interval in minutes, and the factor (1/60) is included to correct the solar radiation "rate" to the proper units of time.

Similarly, the energy flow within a system is given typically by

$$\text{COLLECTED SOLAR ENERGY} = \Sigma\ [\text{M100} \times \Delta H] \times \Delta\tau$$

where M100 is the mass flow rate of the heat transfer fluid in lb_m/min and ΔH is the enthalpy change, in BTU/lb_m, of the fluid as it passes through the heat exchanging component.

For a liquid system ΔH is generally given by

$$\Delta H = \bar{C}_p\ \Delta T$$

where $\bar{C}_p$ is the average specific heat, in BTU/lb_m-°F, of the heat transfer fluid and ΔT, in °F, is the temperature differential across the heat exchanging component.

* See Appendix B.

For an air system ΔH is generally given by

$$\Delta H = H_a(T_{out}) - H_a(T_{in})$$

where $H_a(T)$ is the enthalpy, in BTU/lb_m, of the transport air evaluated at the inlet and outlet temperatures of the heat exchanging component.

$H_a(T)$ can have various forms, depending on whether or not the humidity ratio of the transport air remains constant as it passes through the heat exchanging component.

For electrical power, a general example is

$$\text{ECSS OPERATING ENERGY} = (3413/60)\ \Sigma\ [\text{EP100}] \times \Delta\tau$$

where EP100 is the power required by electrical equipment in kilowatts and the two factors (1/60) and 3413 correct the data to BTU/min.

Letter Designations

C or CP	=	Specific Heat
D	=	Direction or Position
EE	=	Electric Energy
EP	=	Electric Power
F	=	Fuel Flow Rate
HWD	=	Functional procedure to calculate the enthalpy change of water at the average of the inlet and outlet temperatures
H	=	Enthalpy
HR	=	Humidity Ratio
I	=	Incident Solar Flux (Insolation)
M	=	Mass Flow Rate
N	=	Performance Parameter
P	=	Pressure
PD	=	Differential Pressure
Q	=	Thermal Energy
RHO	=	Density
T	=	Temperature
TD	=	Differential Temperature
V	=	Velocity
W	=	Heat Transport Medium Volume Flow Rate
TI	=	Time
_P	=	Appended to a function designator to signify the value of the function during the previous iteration

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

EQUATIONS USED TO GENERATE MONTHLY PERFORMANCE VALUES

WEATHER DATA

AVERAGE AMBIENT TEMPERATURE (^{o}F)

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

AVERAGE BUILDING TEMPERATURE (^{o}F)

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

DAYTIME AVERAGE AMBIENT TEMPERATURE (^{o}F)

$$TDA = (1/360) \times \Sigma\ T001 \times \Delta\tau$$

for $\pm$ three hours from solar noon

COLLECTOR SUBSYSTEM

INCIDENT SOLAR ENERGY PER SQUARE FOOT (BTU/FT^2)

$$SE = (1/60)\ \Sigma\ I001 \times \Delta\tau$$

OPERATIONAL INCIDENT SOLAR ENERGY (BTU)

$$SEOP = (1/60) \times \Sigma\ \{I001 \times CLAREA\} \times \Delta\tau$$

when the collector loop is activated

SOLAR ENERGY COLLECTED BY THE ARRAY (BTU)

$$SECA = \Sigma\ \{M100 \times CP\ (T150 - T100)\} \times \Delta\tau$$

REJECTED SOLAR ENERGY (BTU)

$$CSRJE = \Sigma\ \{M100 \times CP \times (T150 - T151)\} \times \Delta\tau$$

when rejector fan is activated

INCIDENT SOLAR ENERGY ON COLLECTOR ARRAY (BTU)

$$SEA = CLAREA \times SE$$

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

SEC = SECA/CLAREA

COLLECTOR ARRAY EFFICIENCY

CLEF = SECA/SEA

COLLECTOR ARRAY OPERATIONAL EFFICIENCY

CLEFOP = SECA/SEOP

ECSS OPERATING ENERGY (BTU)

$CSOPE = 56.8833 \times \Sigma\ (EP100 + EP101) \times \Delta\tau$

STORAGE SUBSYSTEM

AVERAGE TEMPERATURE OF STORAGE (°F)

$TST = (1/60) \times \Sigma\ \{(T203 + T204)/2\} \times \Delta\tau$

SOLAR ENERGY TO STORAGE (BTU)

$STEI = \Sigma\ \{(M100 - M101) \times CP \times (T200 - T250)\} \times \Delta\tau$

SOLAR ENERGY FROM STORAGE (BTU)

$STEO = \Sigma\ \{M201 \times CP \times (T251 - T201)\} \times \Delta\tau$

CHANGE IN STORED ENERGY (BTU)

$STECH1 = STOCAP \times CP\ (TST1) \times RHO\ (TST1) \times TST1$

$STECH = STECH1 - STECH1_p$

where the subscript $_p$ refers to a prior reference value

TST1 = last hourly storage temperature

STORAGE EFFICIENCY (%)

$STEFF = (STECH + STEO)/STEI \times 100$

STORAGE LOSS (BTU)

$STLOSS = STEI - STEO - STECH$

EFFECTIVE HEAT TRANSFER COEFFICIENT ($BTU/^{\circ}F\text{-}FT^2\text{-}HR$)

$STPER = (1/60) \times \Sigma\ \{SUR\_AREA \times (TST - T001)\} \times \Delta\tau$

SUR_AREA = storage tank surface area

SPACE HEATING SUBSYSTEM

SPACE HEATING LOAD (BTU)

$CDE = \Sigma\ \{M400 \times CP \times (T400 - T450)\} \times \Delta\tau$

EHL = CDE

AUXILIARY BOILER ENERGY (BTU)

$HGB = \Sigma\{M400 \times CP \times (T452 - T402)\} \times \Delta\tau$

SOLAR ENERGY TO SPACE HEATING (BTU)

$HSE = STEO \times CDE/(CDE + TCEI)$

$HSEM = HSE$

SPACE HEATING OPERATING ENERGY (BTU)

$HOPE = 56.8833 \times \Sigma\ (EP401 + EP600) \times \Delta\tau \times CDE/(CDE + TCEI)$

SPACE HEATING AUXILIARY THERMAL ENERGY (BTU)

$HAT = HGB \times CDE/(CDE + TCEI)$

SPACE HEATING AUXILIARY FOSSIL ENERGY (BTU)

$HAF = \Sigma F400 \times CDE/(CDE + TCEI) \times NGC$

$NGC = 1{,}021\ BTU/ft^3$

SPACE HEATING SOLAR FRACTION (%)

$HSFR = 100 \times HSE/(HSE + HAT)$

SPACE HEATING FOSSIL ENERGY SAVINGS (BTU)

$HSVF = HSE/EFF$

EFF - Boiler Efficiency (70%)

SPACE COOLING SUBSYSTEM

SPACE COOLING LOAD (BTU)

$CL = \Sigma \{M500 \times CP \times (T550 - T500)\} \times \Delta\tau$

SOLAR ENERGY TO SPACE COOLING (BTU)

$CSE = STEO \times TCEI/(CDE + TCEI)$

SPACE COOLING OPERATING ENERGY (BTU)

$COPE1 = 56.8833 \times \Sigma\ (EP500 + EP501 + EP502) \times \Delta\tau$

$COPE = 56.8833 \times (EP401 + EP600\} \times \Delta\tau \times TCEI/(CDE + TCEI) + COPE1$

SPACE COOLING AUXILIARY THERMAL ENERGY (BTU)

$CAT = HGB \times TCEI/(CDE + TCEI)$

SPACE COOLING AUXILIARY FOSSIL ENERGY (BTU)

$CAF = \Sigma\ F400 \times TCEI/(CDE + TCEI) \times NGC$

$NGC = 1{,}021\ BTU/ft^3$

SPACE COOLING SOLAR FRACTION (%)

$CSFR = 100 \times CSE/(CSE + CAT)$

SPACE COOLING FOSSIL ENERGY SAVINGS (BTU)

$CSVF = CSE/EFF$

EFF - Boiler Efficiency (70%)

(TCE THERMODYNAMIC CONVERSION EQUIPMENT (CHILLER)

TCE ENERGY INPUT (BTU)

$TCEI = \Sigma\{M400 \times CP \times (T401 - T451)\} \times \Delta\tau$

when EP 502 > 0

TCE LOAD (BTU)

$TCEL = CL$

TCE OPERATING ENERGY (BTU)

$TCEOPE = 56.8833 \times \Sigma\ EP401 \times \Delta\tau \times TCEI/(CDE + TCEI) + COPE1$

TCE REJECTED ENERGY (BTU)

$TCERJE = \Sigma\{M501 \times CP \times (T501 - T551)\} \times \Delta\tau$

TCE COEFFICIENT OF PERFORMANCE

$TCECOP = TCEL/TCEI$

SYSTEM FACTORS

SOLAR ENERGY TO LOADS

$CSEO = CSE + HSE$

SOLAR ENERGY USED

$SEL = CSEO$

ECSS SOLAR CONVERSION EFFICIENCY

$CSCEF = SEL/SEA$

SYSTEM LOAD

$SYSL = CL + EHL$

SYSTEM SOLAR FRACTION

$SFR = (CSFR \times CL + HSFR \times EHL)/SYSL$

SYSTEM OPERATING ENERGY

$SYSOPE = COPE + CSOPE + HOPE$

SYSTEM AUX FOSSIL ENERGY

AXF = HAF + CAF

SYSTEM AUXILIARY THERMAL ENERGY

AXT = HAT + CAT

SYSTEM ELECTRICAL SAVINGS

TSVE = -CSOPE

SYSTEM FOSSIL SAVINGS

TSVF = HSVF + CSVF

TOTAL ENERGY CONSUMED

TECSM = SECA + SYSOPE + AXF

SYSTEM PERFORMANCE FACTOR

SYSPF = SYSL/{AXF + 3.33 x SYSOPE}

EL TORO LIBRARY LONG-TERM WEATHER DATA

COLLECTOR TILT: 19.00 DEGREES
LATITUDE: 33.68 DEGREES

LOCATION: EL TORO, CALIFORNIA
COLLECTOR AZIMUTH: -30.00 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
MAR	2,630	1,611	0.61262	1.118	1,802	279	0	56
APR	3,150	1,928	0.61208	1.034	1,993	177	9	59
MAY	3,489	2,072	0.59393	0.977	2,024	94	29	63
JUN	3,616	2,194	0.60671	0.953	2,090	38	77	66
JUL	3,545	2,363	0.66676	0.962	2,274	0	181	71
AUG	3,273	2,157	0.65896	1.010	2,178	0	209	72
SEP	2,812	1,737	0.61747	1.083	1,881	9	165	70
OCT	2,249	1,357	0.60338	1.181	1,602	64	70	65
NOV	1,762	1,025	0.58169	1.284	1,316	195	12	59

LEGEND:

HOBAR - Monthly average daily extraterrestrial radiation (ideal) in BTU/day-ft^2

HBAR - Monthly average daily radiation (actual) in BTU/day-ft^2.

KBAR - Ratio of HBAR to HOBAR.

RBAR - Ratio of monthly average daily radiation on tilted surface to that on a horizontal surface for each month (i.e., multiplier obtained by tilting).

SBAR - Monthly average daily radiation on a tilted surface (i.e., RBAR x HBAR) in BTU/day-ft^2.

HDD - Number heating degree-days per month.

CDD - Number of cooling degree-days per month.

TBAR - Average ambient temperature in degrees Fahrenheit.

APPENDIX F

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

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

[2] No. 5 and No. 6 fuel oils

APPENDIX G

SENSOR TECHNOLOGY

Temperature Sensors

Temperatures are measured by a Minco Products S53P 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 @ 25°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/°F

WIND SENSOR

Wind speed and direction are measured by a WeatherMeasure W102-P-DC/540 or W101-P-DC/540 wind sensor. Wind speed is measured by means of a four-bladed propeller coupled to a DC generator.

Wind direction is sensed by means of a dual-wiper 1,000-ohm long-life conductive plastic potentiometer. It is attached to the stainless steel shaft which supports and rotates with the upper body assembly.

Size:	29-3/4"L X 30"H
Starting Speed:	1 mph
Complete Tracking:	3 mph
Maximum Speed:	200 mph
Distance Constant (30 mph):	6.2'
Accuracy:	± 1% below 25 mph
	± 3% above 25 mph
Time Constant:	0.145 second

HUMIDITY SENSORS

The WeatherMeasure HMP-14U Solid State Relative Humidity Probe is used for the measurement of relative humidity. The operation of the sensor is based upon the capacitance of the polymer thin film capacitor. A one-micron-thick dielectric polymer layer absorbs water molecules through a thin metal electrode and causes capacitance change proportional to relative humidity.

Range:	0-100% R.H.
Response Time:	1 second to 90% humidity change at 20°C
Temperature Coefficient:	0.05% R.H./°C
Accuracy:	± 3% from 0-80% R.H. ± 5-6% 80-100% R.H.
Sensitivity:	0.2% R.H.

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. Pyranometers designated as shadowband pyranometers are equipped with a shadowband which may be adjusted to block out any direct solar radiation. These instruments are used for the measurement of diffuse insolation.

Sensitivity:	9 μ $V/W/m^2$
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

LIQUID FLOW SENSORS (NONTOTALIZING)

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.

Materials:	Target - 17-PH stainless steel Body - Brass or stainless steel Seals - Buna-N
Fluid Temperature:	-40°F to 250°F
Calibration Accuracy:	± 1% (½" to 3½" line size) ± 2% (4" and greater line size)
Repeatability and Hysteresis:	0.25% of reading

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%	

AIR FLOW SENSORS

The Kurz 430 Series of thermal anemometers is used for the measurement of air flow. The basic sensing element is a probe which consists of a velocity sensor and a temperature sensor. The velocity sensor is heated and operated as a constant temperature thermal anemometer which responds to a "standard" velocity (referenced to 25°C and 760 mm Hg) or mass flow by sensing the cooling effect of the air as it passes over the heated sensor. The temperature sensor compensates for variations in ambient temperature.

Since the probe measures air velocity at only one point in the cross section of the duct, it is necessary to perform a careful duct mapping to relate the probe reading to the amount of air flowing through the entire duct. This is done by dividing the duct into small areas and taking a reading at the center of each area using a portable probe. The readings are then averaged to determine the overall duct velocity. The reading at the permanently installed probe is then ratioed to this reading. This duct mapping is done for each mode.

Accuracy:	± 2% of full scale over temperature range -20°C to 60°C ± 5% of full scale over temperature range -60°C to 250°C
Response Time:	0.025 second
Repeatability:	0.25% full scale

FUEL OIL FLOW SENSOR

The Kent Mini-Major is used as a flow 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

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

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

HEAT FLUX SENSORS

The Hy-Cal Engineering Model BI-7X heat flow sensor is used for the measurement of heat flux. The sensor consists basically of an insulating wafer, with a series of thermocouples arranged such that consecutive thermoelectric junctions fall on opposite sides of the wafer. This assembly is bonded to a heat sink to assure heat flow through the sensor. Heat is received on the exposed surface of the wafer and conducted through the heat sink. A temperature drop across the wafer is thus developed and is measured directly by each junction combination embodied along the wafer. Since the differential thermocouples are connected electrically in series, the voltages produced by each set of junctions is additive, thereby amplifying the signal directly proportional to the number of junctions. The temperature drop across the wafer, and thus the output signal, is directly proportional to the heating rate.

Operation Temperature:	-50° to 200°F
Response Time:	6 seconds
Linearity:	2%
Repeatability:	0.5%
Sensitivity:	2 mv/BTU/ft^2-hr
Size:	2" X 2"

MONTHLY REPORT: SEPTEMBER 1981
SITE SUMMARY: EL TORO LIBRARY P2455

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	77.588 MILLION BTU
	54372 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	24.130 MILLION BTU
	16909 BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	56 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.311
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	0.336
AVERAGE AMBIENT TEMPERATURE	74 DEGREES F
AVERAGE BUILDING TEMPERATURE	76 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.18
ECSS OPERATING ENERGY	0.503 MILLION BTU
ECSS PERFORMANCE FACTOR	9531 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	13.027 MILLION BTU
TOTAL ENERGY CONSUMED	122.027 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	1360 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	5826 BTU/SQ.FT.

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	39.956	39.956 MILLION BTU
SOLAR FRACTION	N.A.	0	20	20 PERCENT
SOLAR SAVINGS RATIO	N.A.	0.000	0.196	0.339
SOLAR ENERGY USED	N.A.	0.000	13.601	13.601 MILLION BTU
OPERATING ENERGY	N.A.	0.000	12.525	13.027 MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.000	58.256	58.256 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	0.000	84.718	84.718 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.503 MILLION BTU
FOSSIL SAVINGS	N.A.	0.000	19.430	19.430 MILLION BTU

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, JUNE 1980.
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MONTHLY REPORT: SEPTEMBER 1981
SITE SUMMARY: EL TORO LIBRARY P2455

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	77.588 MILLION BTU
	54372 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	24.130 MILLION BTU
	16909 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	74 DEGREES F
AVERAGE BUILDING TEMPERATURE	76 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.18
ECSS OPERATING ENERGY	0.503 MILLION BTU
STORAGE EFFICIENCY	61.56 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.485 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	13.027 MILLION BTU
TOTAL ENERGY CONSUMED	122.027 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	39.956	39.956 MILLION BTU
SOLAR FRACTION	N.A.	0	20	20 PERCENT
SOLAR ENERGY USED	N.A.	0.000	13.601	13.601 MILLION BTU
OPERATING ENERGY	N.A.	0.000	12.525	13.027 MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.000	58.256	58.256 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	0.000	84.718	84.718 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.503 MILLION BTU
FOSSIL SAVINGS	N.A.	0.000	19.430	19.430 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.31
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.14

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REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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MONTHLY REPORT: SEPTEMBER 1981
SITE SUMMARY: EL TORO LIBRARY P2455

				SI UNITS
GENERAL SITE DATA:				
INCIDENT SOLAR ENERGY				81.856 GIGA JOULES
				617446 KJ/SQ.M.
COLLECTED SOLAR ENERGY				25.457 GIGA JOULES
				192024 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE				23 DEGREES C
AVERAGE BUILDING TEMPERATURE				24 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY				0.18
ECSS OPERATING ENERGY				0.530 GIGA JOULES
STORAGE EFFICIENCY				61.56 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT				2.756 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY				13.744 GIGA JOULES
TOTAL ENERGY CONSUMED				128.739 GIGA JOULES
SUBSYSTEM SUMMARY:				
	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	42.153	42.153 GIGA JOULES
SOLAR FRACTION	N.A.	0	20	20 PERCENT
SOLAR ENERGY USED	N.A.	0.000	14.349	14.349 GIGA JOULES
OPERATING ENERGY	N.A.	0.000	13.214	13.744 GIGA JOULES
AUX. THERMAL ENG	N.A.	0.000	61.460	61.460 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	N.A.	0.000	89.377	89.377 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.530 GIGA JOULES
FOSSIL SAVINGS	N.A.	0.000	20.499	20.499 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.31

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.14

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REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	2.886	74	-0.447	N	0.015	0.000	-0.155
2	2.956	75	0.623	O	0.016	0.000	0.211
3	2.888	74	0.624	T	0.016	0.000	0.216
4	2.694	75	0.527		0.015	0.000	0.196
5	1.922	71	0.383	A	0.011	0.000	0.199
6	2.599	76	0.000	P	0.035	0.189	0.000
7	2.865	79	0.961	P	0.017	0.000	0.335
8	2.901	82	0.683	L	0.017	0.000	0.235
9	2.971	80	0.638	I	0.018	0.000	0.215
10	2.798	73	0.575	C	0.015	0.000	0.206
11	2.884	76	0.613	A	0.017	0.000	0.213
12	2.764	74	0.575	B	0.015	0.000	0.208
13	2.918	77	0.000	L	0.042	0.279	0.000
14	2.799	74	0.497	E	0.017	0.000	0.178
15	2.705	73	0.646		0.018	0.000	0.239
16	2.702	75	0.627		0.018	0.008	0.232
17	2.754	77	0.635		0.018	0.000	0.231
18	2.333	80	0.567		0.017	0.000	0.243
19	2.709	80	0.680		0.018	0.000	0.251
20	2.786	75	0.000		0.000	0.000	0.000
21	2.843	73	0.324		0.012	0.051	0.114
22	2.668	69	0.640		0.016	0.000	0.240
23	2.599	70	0.550		0.016	0.000	0.211
24	2.476	70	0.417		0.015	0.000	0.168
25	2.563	68	0.493		0.016	0.000	0.192
26	2.605	70	0.761		0.016	0.002	0.292
27	2.292	68	0.000		0.014	0.000	0.000
28	2.211	68	0.695		0.014	0.000	0.314
29	0.873	66	0.017		0.014	0.000	0.020
30	1.623	67	0.297		0.014	0.001	0.183
SUM	77.588	-	13.601	N.A.	0.503	0.531	-
AVG	2.586	74	0.453	N.A.	0.017	0.018	0.175
PFRV	1.0000	0.9972	0.9986	N.A.	1.0000	0.9972	0.9986

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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	2.886	2.766	1.007	86	0.349	0.364
2	2.956	2.890	1.098	87	0.372	0.380
3	2.888	2.776	1.053	83	0.365	0.379
4	2.694	2.603	0.951	88	0.353	0.365
5	1.922	1.785	0.666	78	0.346	0.373
6	2.599	2.485	0.855	87	0.329	0.344
7	2.865	2.822	0.953	91	0.333	0.338
8	2.901	2.869	1.009	100	0.348	0.352
9	2.971	2.954	1.019	98	0.343	0.345
10	2.798	2.724	0.952	88	0.340	0.349
11	2.884	2.833	0.978	91	0.339	0.345
12	2.764	2.640	0.928	88	0.336	0.351
13	2.918	2.880	0.878	94	0.301	0.305
14	2.799	2.742	0.812	89	0.290	0.296
15	2.705	2.701	0.843	87	0.312	0.312
16	2.702	2.690	0.833	89	0.308	0.310
17	2.754	2.743	0.900	92	0.327	0.328
18	2.333	2.321	0.748	95	0.320	0.322
19	2.709	2.701	0.890	96	0.329	0.330
20	2.786	0.000	0.000	90	0.000	0.000
21	2.843	1.940	0.753	86	0.265	0.388
22	2.668	2.629	0.851	79	0.319	0.323
23	2.599	2.542	0.826	78	0.318	0.325
24	2.476	1.995	0.632	80	0.255	0.317
25	2.563	2.520	0.792	79	0.309	0.314
26	2.605	2.573	0.890	81	0.342	0.346
27	2.292	2.224	0.673	79	0.294	0.303
28	2.211	2.158	0.750	81	0.339	0.348
29	0.873	0.804	0.121	72	0.139	0.150
30	1.623	1.584	0.470	75	0.289	0.296
SUM	77.588	71.896	24.130	-	-	-
AVG	2.586	2.397	0.804	86	0.311	0.336
PFRV	1.0000	0.9972	0.9972	0.9972	0.9972	0.9972

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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

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	0.978	-0.452	0.203	162	2.30
2	1.033	0.623	0.024	171	0.67
3	1.006	0.624	-0.028	170	0.71
4	0.917	0.527	0.061	169	0.58
5	0.617	0.383	-0.024	170	0.43
6	0.563	0.000	0.437	190	0.18
7	0.916	0.961	-0.393	184	0.55
8	0.928	0.683	-0.049	172	0.54
9	0.942	0.638	0.001	169	0.56
10	0.893	0.575	0.014	170	0.52
11	0.886	0.613	0.057	171	0.37
12	0.860	0.575	-0.010	173	0.50
13	0.508	0.000	0.399	193	0.15
14	0.769	0.497	-0.152	196	0.58
15	0.789	0.646	-0.246	185	0.57
16	0.814	0.627	-0.022	173	0.36
17	0.822	0.635	0.007	172	0.31
18	0.686	0.567	0.004	171	0.21
19	0.823	0.680	0.027	172	0.21
20	0.000	0.000	-0.060	173	0.10
21	0.692	0.324	0.079	170	0.49
22	0.797	0.640	-0.107	170	0.43
23	0.779	0.550	-0.024	165	0.44
24	0.591	0.417	0.002	164	0.31
25	0.773	0.493	-0.007	162	0.51
26	0.861	0.761	-0.202	153	0.60
27	0.617	0.000	0.517	168	0.17
28	0.731	0.695	-0.426	163	0.81
29	0.094	0.017	0.019	154	0.11
30	0.441	0.297	-0.004	152	0.29
SUM	22.125	13.595	0.025	-	-
AVG	0.738	0.453	0.001	171	0.49
PFRV	0.9972	1.0000	N.A.	1.0000	0.9972

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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

SPACE COOLING SUBSYSTEM

DAY OF MONTH (NBS ID)	SPACE COOLING LOAD MILLION BTU (Q502)	SOLAR FRACTION OF LOAD PERCENT (N500)	SOLAR ENERGY USED MILLION BTU (Q500)	OPER ENERGY MILLION BTU (Q503)	AUX THERMAL USED MILLION BTU (Q501)	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q508)	ELECT ENERGY SAVINGS MILLION BTU (Q512)	FOSSIL ENERGY SAVINGS MILLION BTU (Q514)	BLDG DRY BULB TEMP DEG F (N406)	AMB TEMP DEG F (N113)
1	1.933	39	-0.447	0.558	2.798	N	4.242	N	-0.638	76	74
2	1.983	18	0.623	0.557	2.727	O	3.899	O	0.890	76	75
3	2.055	17	0.624	0.576	2.779	T	4.207	T	0.892	75	74
4	1.607	19	0.527	0.455	2.215		3.322		0.752	75	75
5	1.577	14	0.383	0.445	2.223	A	3.387	A	0.547	75	71
6	0.000	0	0.000	0.000	0.000	P	0.000	P	0.000	78	76
7	1.325	39	0.961	0.389	1.410	P	2.042	P	1.373	75	79
8	2.043	19	0.683	0.579	2.714	L	4.016	L	0.975	75	82
9	1.579	23	0.638	0.555	2.167	I	3.295	I	0.911	73	80
10	1.992	16	0.575	0.570	2.883	C	4.345	C	0.822	73	73
11	1.529	21	0.613	0.439	2.227	A	3.323	A	0.876	74	76
12	1.484	21	0.575	0.428	2.191	B	3.168	B	0.822	74	74
13	0.000	0	0.000	0.000	0.000	L	0.000	L	0.000	77	77
14	0.965	27	0.497	0.296	1.303	E	2.012	E	0.710	74	74
15	1.910	19	0.646	0.567	2.735		4.139		0.922	74	73
16	1.887	17	0.627	0.562	2.841		4.192		0.896	74	75
17	1.885	17	0.635	0.568	2.816		3.854		0.907	75	77
18	1.497	20	0.567	0.442	3.170		2.719		0.810	76	80
19	1.511	24	0.680	0.433	2.070		2.876		0.972	76	80
20	0.000	0	0.000	0.000	0.000		0.000		0.000	79	75
21	1.014	15	0.324	0.311	1.606		2.418		0.464	76	73
22	1.971	18	0.640	0.577	2.889		4.417		0.914	74	69
23	1.882	15	0.550	0.559	2.963		4.520		0.785	73	70
24	1.903	12	0.417	0.562	3.039		4.582		0.595	74	70
25	0.840	20	0.493	0.396	1.262		1.852		0.704	76	68
26	0.247	99	0.761	0.367	0.052		0.001		1.087	80	70
27	0.000	0	0.000	0.000	0.000		0.000		0.000	85	68
28	0.323	92	0.695	0.292	0.057		0.051		0.993	83	68
29	1.949	0	0.017	0.548	3.250		5.014		0.024	77	66
30	1.067	-2	0.297	0.491	1.866		2.827		0.425	77	67
SUM	39.956	-	13.601	12.525	58.256	N.A.	84.718	N.A.	19.430	-	-
AVG	1.332	20	0.453	0.417	1.942	N.A.	2.824	N.A.	0.648	76	74
PFRV	1.0000	0.9986	0.9986	0.9986	0.9986	N.A.	0.9986	N.A.	0.9986	1.00	0.9972

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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

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)
1	2022	N	74	86	N	N	N
2	2072	O	75	87	O	O	O
3	2024	T	74	83	T	T	T
4	1888		75	88			
5	1347	A	71	78	A	A	A
6	1821	P	76	87	P	P	P
7	2008	P	79	91	P	P	P
8	2033	L	82	100	L	L	L
9	2082	I	80	98	I	I	I
10	1961	C	73	88	C	C	C
11	2021	A	76	91	A	A	A
12	1937	B	74	88	B	B	B
13	2045	L	77	94	L	L	L
14	1962	E	74	89	E	E	E
15	1896		73	87			
16	1893		75	89			
17	1930		77	92			
18	1635		80	95			
19	1899		80	96			
20	1953		75	90			
21	1992		73	86			
22	1870		69	79			
23	1822		70	78			
24	1735		70	80			
25	1796		68	79			
26	1826		70	81			
27	1606		68	79			
28	1550		68	81			
29	612		66	72			
30	1137		67	75			
SUM	54372	N.A.	-	-	-	-	-
AVG	1812	N.A.	74	86	N.A.	N.A.	N.A.
PFRV	1.0000	N.A.	0.9972	0.9972	N.A.	N.A.	N.A.

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MONTHLY REPORT: EL TORO LIBRARY P2455 SEPTEMBER 1981

THERMODYNAMIC CONVERSION EQUIPMENT

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	1.933	3.046	0.365	5.367	0.633
2	1.983	3.191	0.365	5.590	0.621
3	2.055	3.282	0.379	5.745	0.626
4	1.607	2.613	0.304	4.436	0.615
5	1.577	2.450	0.297	4.318	0.644
6	0.000	0.000	0.005	0.000	0.000
7	1.325	2.612	0.261	3.665	0.507
8	2.043	3.278	0.385	5.473	0.623
9	1.579	3.658	0.361	4.561	0.432
10	1.992	3.401	0.385	5.650	0.586
11	1.529	2.708	0.299	4.430	0.565
12	1.484	2.867	0.291	4.416	0.518
13	0.000	0.000	0.005	0.000	0.000
14	0.965	1.903	0.204	2.892	0.507
15	1.910	3.950	0.387	5.604	0.483
16	1.887	3.767	0.384	5.368	0.501
17	1.885	3.736	0.388	5.378	0.504
18	1.497	3.659	0.302	3.975	0.409
19	1.511	2.652	0.296	4.111	0.570
20	0.000	0.000	0.005	0.000	0.000
21	1.014	1.881	0.219	3.031	0.539
22	1.971	3.397	0.396	5.723	0.580
23	1.882	3.463	0.378	5.647	0.544
24	1.903	3.358	0.379	5.596	0.567
25	0.840	3.507	0.256	2.726	0.239
26	0.247	3.145	0.231	1.211	0.079
27	0.000	0.000	0.005	0.000	0.000
28	0.323	0.981	0.188	1.185	0.329
29	1.949	3.327	0.369	5.499	0.586
30	1.067	3.306	0.315	3.466	0.323
SUM	39.956	79.137	8.403	115.065	-
AVG	1.332	2.638	0.280	3.835	0.505
PFRV	1.0000	0.9986	0.9986	1.0000	0.9986

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*U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2963