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OAKMEAD INDUSTRIES

SANTA CLARA, CALIFORNIA

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

OCTOBER 1980 THROUGH MAY 1981

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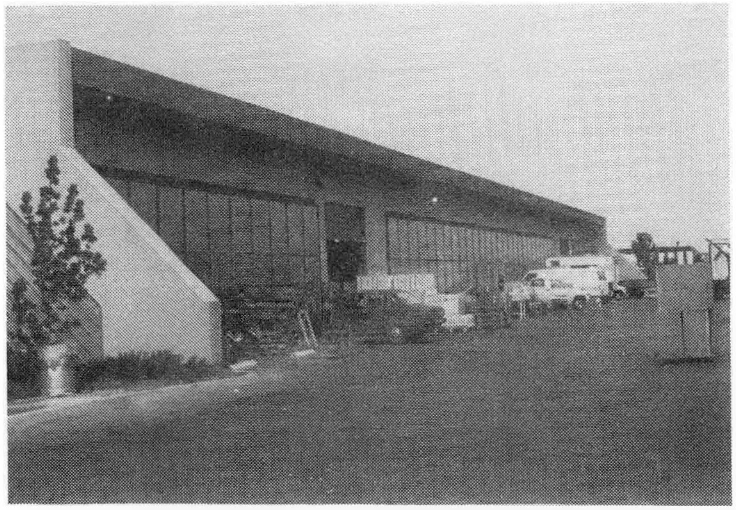
FOREWORD

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.

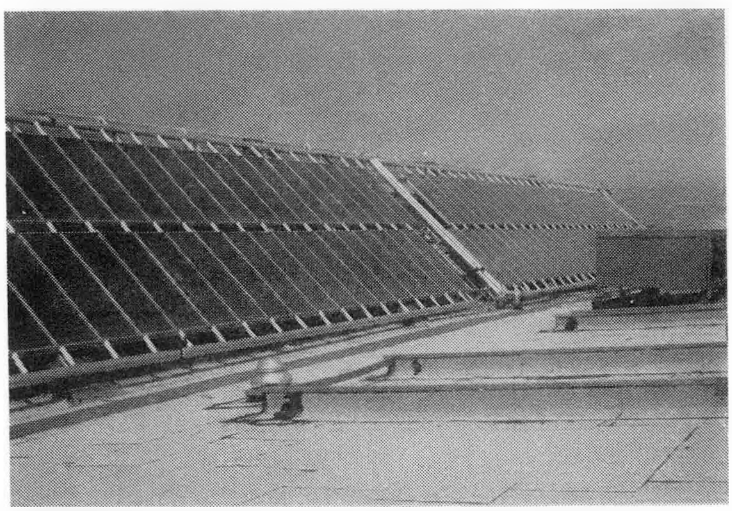
The National Solar Data Network consists of instrumented solar energy systems in buildings selected from among the 5,000 installations built (since early 1977) as part of the National Solar Heating and Cooling Demonstration Program. The overall purpose of this program is to assist in the development 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.

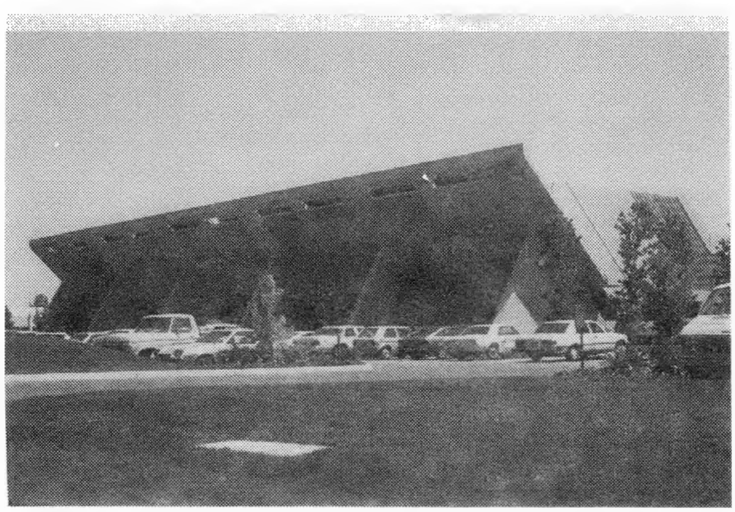
The buildings in the NSDN program are instrumented to monitor thermal energy flows to the space conditioning, hot water, or process loads, from both the solar system and the auxiliary or backup system. Data collection from each site, and transmission to a central computer for processing and analysis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



Air Collectors on South Wall



Liquid Collector Array on North Facia



Oakmead Industries Solar Site

OAKMEAD INDUSTRIES

OAKMEAD INDUSTRIES

The Oakmead Industries solar energy system is a commercial office/manufacturing building located in Santa Clara, California.

It is equipped with:

Collector	2,622 square feet of Revere Sun-Aid collectors (liquid flat-plate) 1,675 square feet of glazing for south wall
Storage	6,500-gallon steel storage tank
Auxiliary	Space Heating - two gas-fired heating units (400,000 BTU furnace) DHW - electric resistance type heater (National)

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OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

Solar Fraction[1]	54%
Solar Savings Ratio[2]	0.52
Conventional Fuel Savings[3]	413,190 cubic feet of natural gas and 8,436 kwh of electrical energy
System Performance Factor[4]	0.75
Solar System COP[5]	23.87

Seasonal Energy Requirements
October 1980 through May 1981
(Million BTU)

	Total Load	Solar Contribution	% Solar
Heating	441.89	253.12	57
Hot Water	104.69	41.14	39

Environmental Data

	Measured Average	Long-Term Average
Outdoor temperature	61°F	56°F
Heating degree-days	1,292	2,326
Cooling degree-days	271	51
Daily incident solar energy	1,476 BTU/ft^2	1,551 BTU/ft^2

1. $$\text{Solar Fraction} = \frac{\text{Solar Energy Supplied to Load}}{\text{Total Load}} \times 100$$

2. $$\text{Solar Savings Ratio} = \frac{\text{Solar Energy Supplied to Load} - \text{Solar Unique Operating Energy}}{\text{Total Load}}$$

3. $$\text{Conventional Fuel Savings} = \begin{cases} \text{Savings in BTU's} \times 979.4 \times 10^{-6}\ \text{ft}^3/\text{BTU} \\ \text{Savings in BTU's} \times 292.8 \times 10^{-6}\ \text{kwh/BTU} \end{cases}$$

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

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

1.1 SUMMARY AND CONCLUSIONS

The Oakmead Industries solar energy system supplied a significant portion of the building load during the October 1980 through May 1981 period. The solar system supplied 54% of the space heating and domestic hot water (DHW) loads. The solar system provided a savings of 4,132 therms of natural gas and 8,436 kwh of electrical energy. These savings are equivalent to $2,095.90, based on estimated fuel rates at the site of 44.6 cents per hundred cubic feet of natural gas and $0.03 per kwh of electricity. The thermal performance of the system is summarized in Table 1.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 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 (%)
				THERMAL	FOSSIL	ELECTRICAL		FOSSIL	ELECTRICAL	
OCT	40.78E	35.30	28.92	6.47	0.78	6.00	7.17	26.83	11.97	82
NOV	39.21	59.83	27.41	32.42	43.78	6.15	7.87	33.52	6.13	46
DEC	60.76	118.43	53.46	64.99	91.86	9.88	10.59	87.10	-1.12	45
JAN	47.54	107.26	39.90	67.36	95.85	9.85	10.29	65.60	-1.46	37
FEB	48.90	65.02	41.06	23.95	25.13	8.88	7.16	63.27	1.73	63
MAR	61.83	91.15	51.86	39.36	48.91	10.02	9.90	83.47	-0.15	57
APR	66.13	52.26	40.49	11.88	8.37	6.85	4.60	56.19	5.56	77
MAY	48.46	17.33	11.16	6.17	0.42	5.92	1.67	5.90	6.15	64
TOTAL	413.61	546.58	294.26	252.60	315.10	63.55	59.25	421.88	28.81	-
AVERAGE	51.70	68.32	36.78	31.58	39.39	7.94	7.41	52.74	3.60	54(1)

E - Denotes estimated value.
(1) Weighted average.

Several minor problems were encountered during the period, with a small impact on system performance. These included collector control problems, incorrect time clock settings for the north zone heating distribution subsystem, a failure of pump P2 in November 1980, a larger than expected DHW load, and an improper control set point for the solar preheating DHW mode. These problems are summarized below and are discussed in more detail in the Subsystem Performance sections.

The liquid collector subsystem experienced intermittent control problems, which caused the collector and thermal control loop (TCL) pumps, P1 and P3 to run all day and night. Although the problem occurred sporadically, it decreased collector subsystem and system performance by rejecting stored energy through the collectors. Despite this control failure, the collector subsystem was able to maintain an average operational efficiency of 45%.

The performance of the air collector subsystem could have been improved. Some of the potentially available solar energy could not be utilized due to the control set point being too high. If adjusted, the performance would have improved.

The time clocks for the space heating subsystem were set incorrectly which increased the space heating load for the building. The time clocks activated the heating system too early in the morning which increased the usage of auxiliary energy. If the time clocks had been operating properly, the space heating load would have been smaller and system performance would have improved.

Solar space heating pump P2 failed to operate on the first 14 days of November. This failure prevented the delivery of solar energy for space heating and lowered system performance.

Due to a higher than expected DHW demand, pump P4 between solar storage and the DHW preheat tank was to be replaced with a larger pump to accommodate the higher load. However, pump P4 has not been replaced and the solar contribution is lower. Also the DHW controller set point was 5°F-10°F too high, which resulted in less solar energy being delivered to the DHW subsystem.

All these problems contributed to the lower than expected performance, but the solar system still attained a solar fraction of 54%.

The summation of solar energy used and auxiliary thermal energy does not always equal the system load. These small differences are due to minor problems in the software bridging program. The interpolation of small amounts of missing data sometimes caused the sum of the solar and auxiliary energies not to equal the system load. The maximum difference is 0.25%.

A graphical representation of the system thermal performance is depicted in Figure 1. This figure demonstrates the difference between solar energy and auxiliary energy used at Oakmead Industries. This figure represents a solar contribution of 54%. System operating energy is also shown to visualize the quantity of operating energy compared to the total energy needed to support the loads.

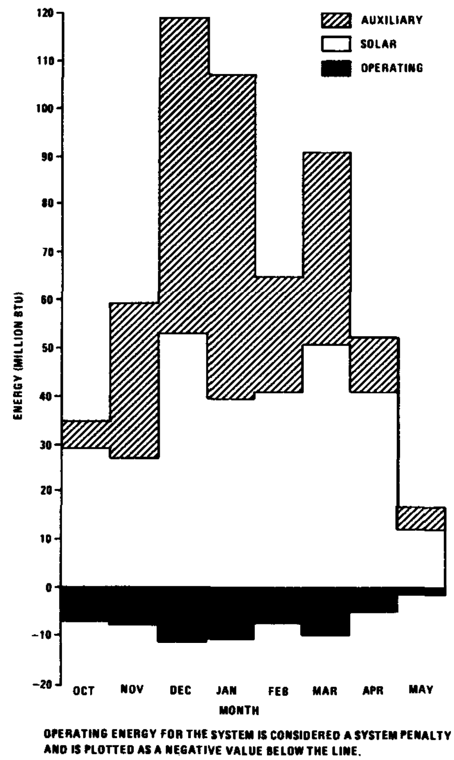

Figure 1. System Thermal Performance
Oakmead Industries
October 1980 through May 1981

The flow of solar energy through the Oakmead Industries solar system is presented in Figure 2. This 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 energy collection and good distribution to the loads. A high loss of 82.32 million BTU is noted between the liquid collector and storage tank. This loss represents collector loop losses, storage to load loop losses, and energy losses in April and May when the north zone solar control continually delivered solar energy when there was no space heating load.

The solar energy coefficient of performance (COP) is presented 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 at Oakmead Industries performed at a weighted seasonal average solar COP value of 23.87. The collector subsystem functioned at a COP of 46.01, the DHW subsystem COP was 73.46 and the space heating subsystem COP was 91.05. The high COPs represent a low operating energy expenditure compared to solar energy used, resulting in increased energy savings.

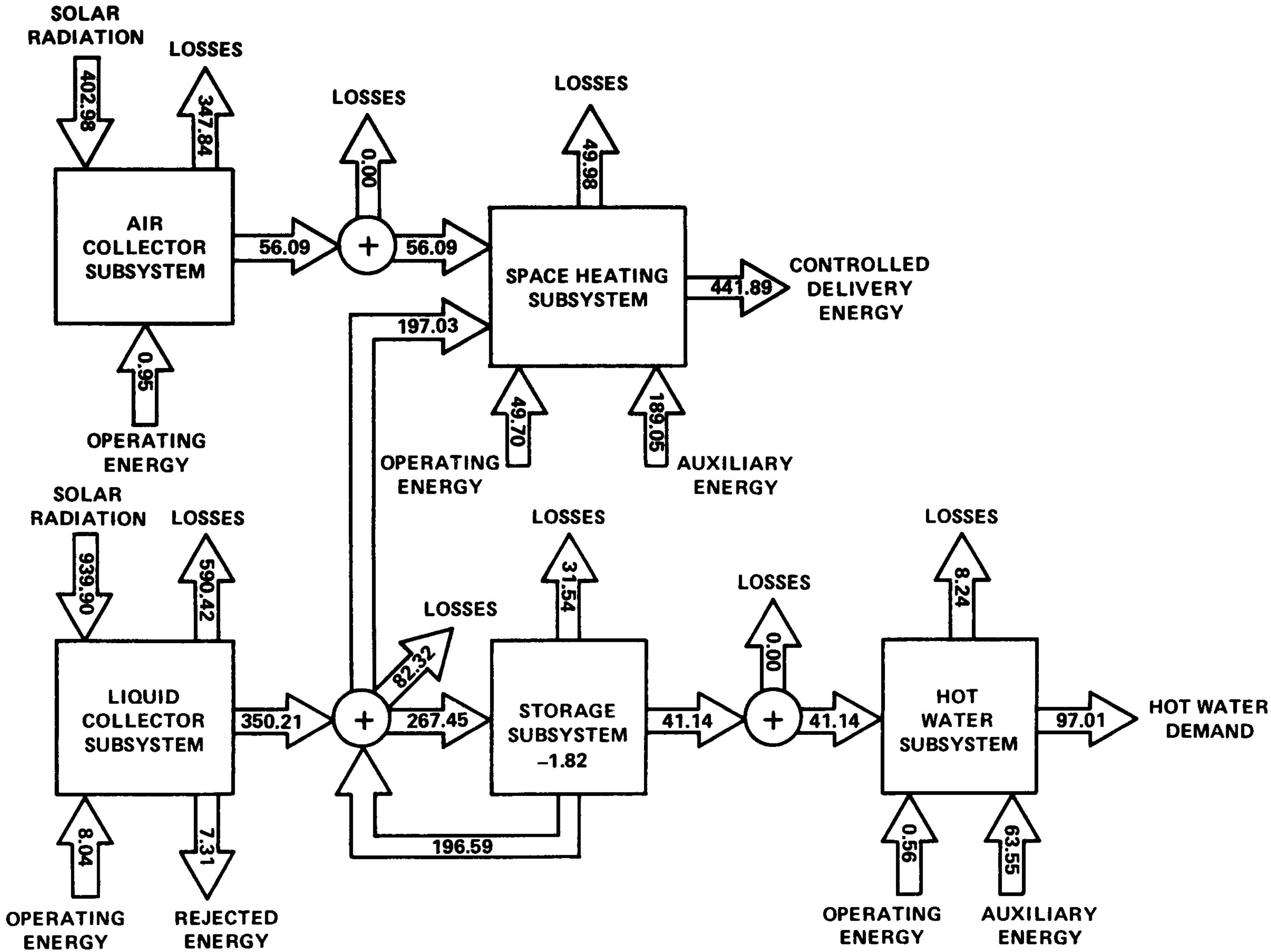

Figure 2. Energy Flow Diagram for Oakmead Industries
October 1980 through May 1981
(Figures in million BTU)

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	DOMESTIC HOT WATER SOLAR	SPACE HEATING SOLAR
OCT	34.02	67.97	85.47	161.00
NOV	9.54	45.59	81.11	91.41
DEC	23.04	32.15	40.00	130.65
JAN	19.95	28.99	27.00	115.76
FEB	29.75	54.94	44.29	90.38
MAR	26.87	42.06	44.50	119.24
APR	33.20	81.64	84.75	102.18
MAY	7.59	57.69	95.25	6.44
WEIGHTED AVERAGE	23.87	46.01	73.46	91.05

1.2 SYSTEM OPERATION

1.2.1 TYPICAL SYSTEM OPERATION

February 3, 1981 represents a sunny day of system operation for the liquid collector subsystem. Typical air subsystem operation is not shown because it operated too sporadically. The variation of key system parameters for this day is presented in Figures 3a, 3b, and 3c. Figure 3a shows the solar radiation upon the liquid system collector array during the day. Some cloud cover was noticed in the afternoon between 1330 and 1400 hours. The period during which collector loop pump P1 was operational is indicated.

Figure 3b depicts the liquid collector absorber plate and array inlet and outlet temperatures during the day. The collector pump is activated when the collector absorber plate temperature is 5°F higher than the temperature in the thermal control loop (TCL). (Refer to System Description in Appendix A) During startup conditions, the collector absorber plate temperature rises and then falls as a result of cold fluid entering the collector panel from the pipe lines. The fluid in the collector inlet pipe line was very cold (40°F) at the location of the sensor. This condition occurred at 0835, and the collector pump was then deactivated because the temperature differential between plate and storage became too small. At 0851 the collector pump was activated again and remained on until the end of the day when the differential control device fell below the set point. The collector inlet and outlet temperatures show a fairly consistent gradient resulting in good collector performance. The collector absorber plate temperature remained consistently higher than the array inlet and outlet temperatures as expected. Once the collector pumps turned off at 1636, the collector array temperature declined due to losses to the ambient. That period when the collector loop pump P1 was operating is indicated.

The storage tank temperature profile is presented in Figure 3c. Due to the improper setting on the time clocks, the building began using solar energy from storage at 0330. The temperatures in the tank declined until about 1046 when energy was added to storage from the collector loop. The heating load at this time was satisfied so energy was added to storage and the temperatures in the tank increased to 125°F. From 1046 until 1600 hours, the middle tank temperature was greater than the top tank temperature. Solar energy always enters the middle of the storage tank and is usually taken from the top of the tank. The temperature profile clearly shows the middle of the tank being warmer, which is exactly where sensor T203 is located. This sensor indicates the temperature before mixing with the remaining fluid. At approximately 1547, the space heating load increased again and energy was removed from storage to meet the space heating demand. A similar pattern occurred throughout the heating season.

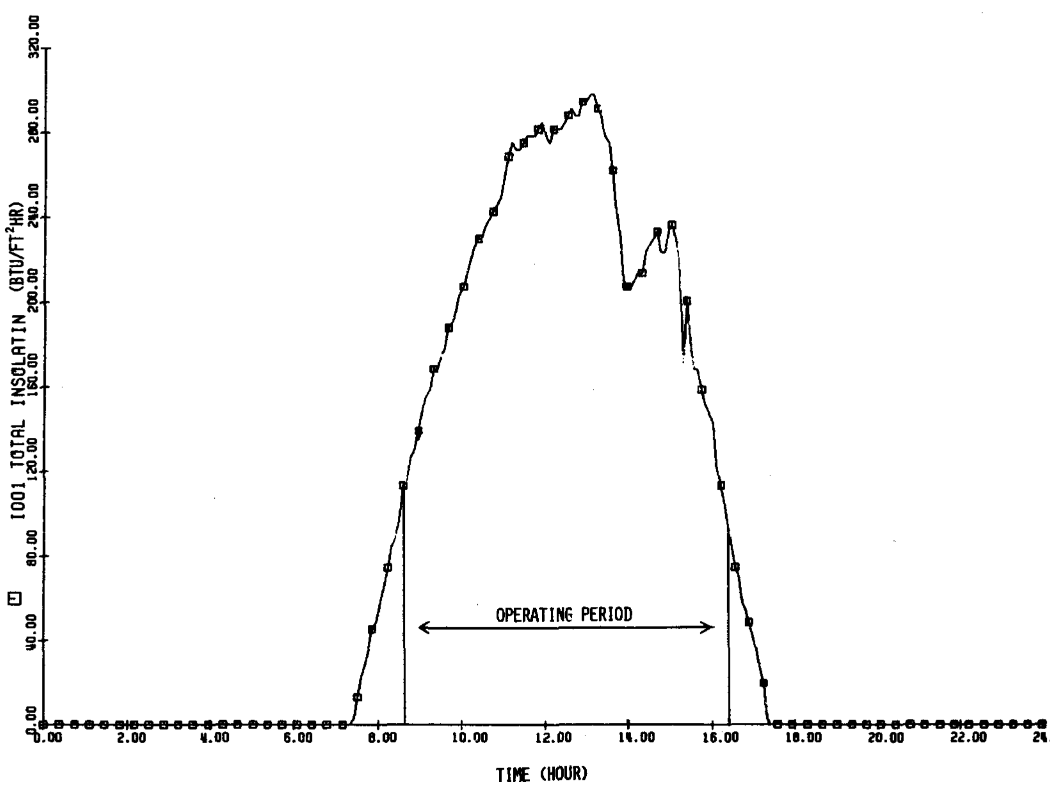

Figure 3a. Typical Insolation Data
Oakmead Industries
February 3, 1981

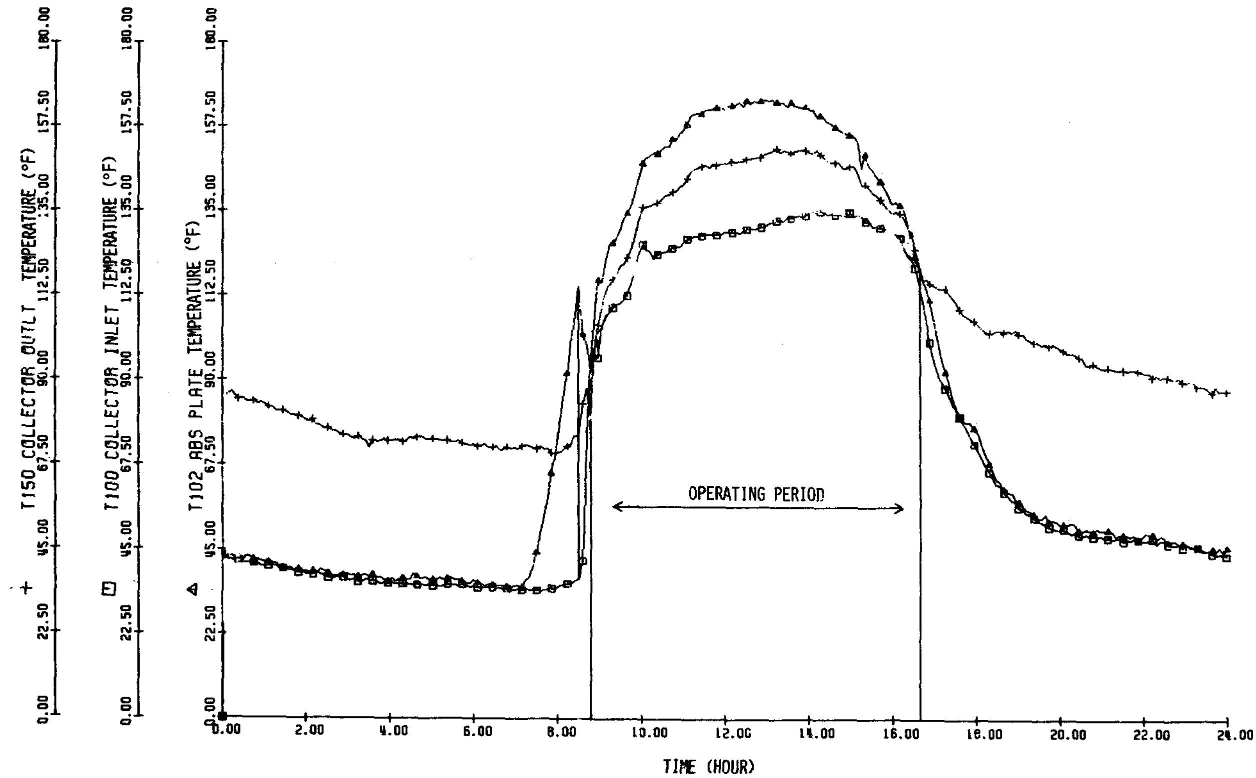

Figure 3b. Typical Collector Array Temperatures, Inlet/Outlet
Oakmead Industries
February 3, 1981

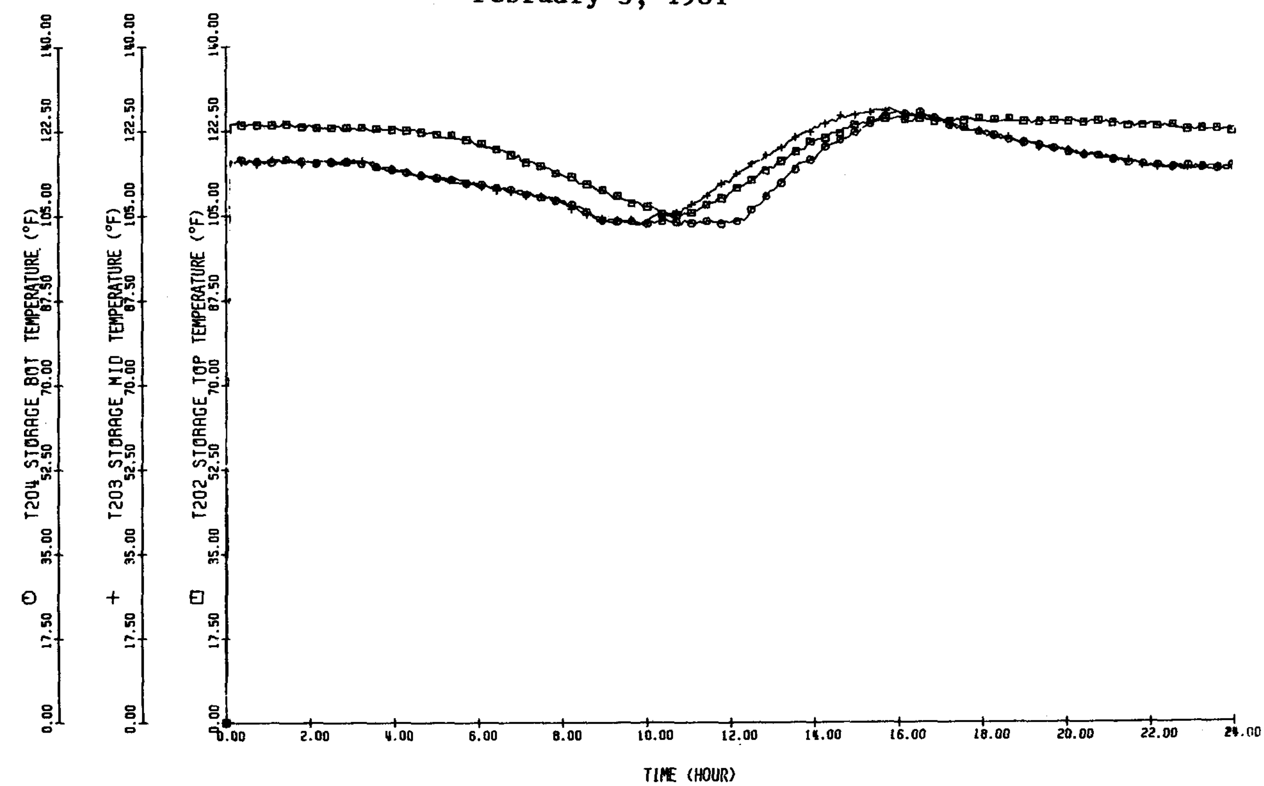

Figure 3c. Typical Storage Fluid Temperatures
Oakmead Industries
February 3, 1981

1.2.2 SYSTEM OPERATING SEQUENCE

Figure 4 presents a bar chart showing typical system operating sequences for February 3, 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, it is possible to deliver solar energy to storage and space heating at the same time. This is made possible by the thermal control loop (TCL). Secondly, the auxiliary space heating unit usually operates in conjunction with the delivery of solar energy due to the type of space heating controls at this site. Also, the DHW electric heater operates throughout the night to maintain the set point temperature in the tank. A major portion of the DHW load occurs during the day when large quantities of DHW are consumed.

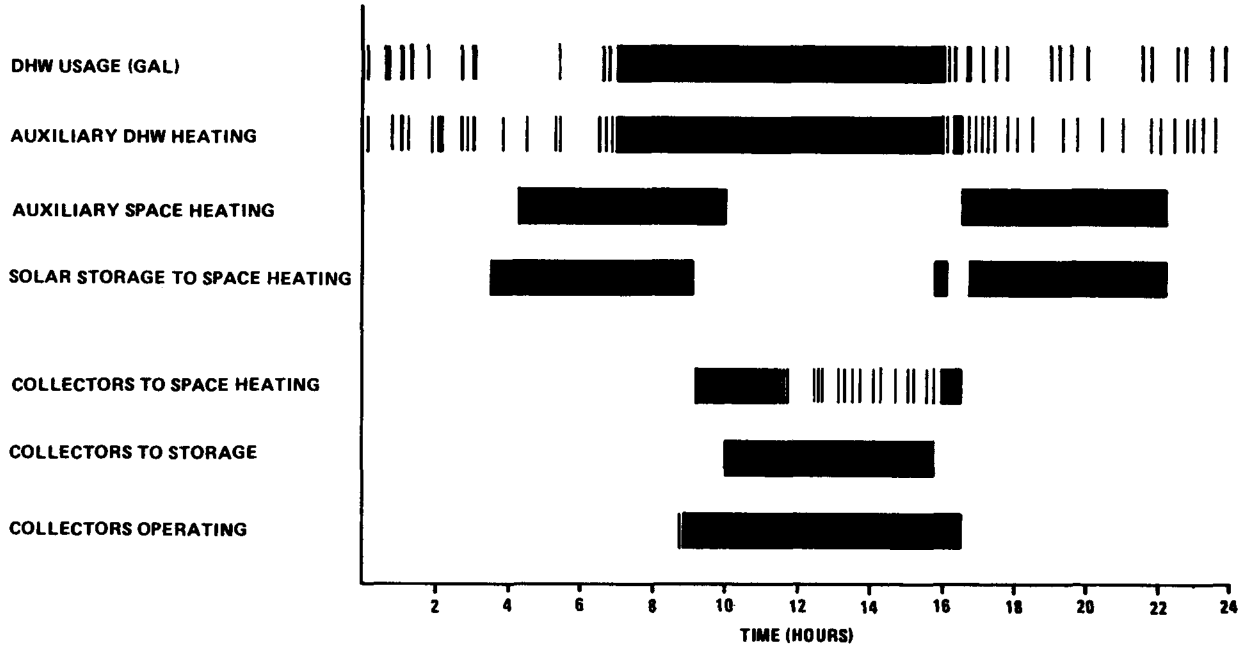

Figure 4. Typical System Operating Sequence
Oakmead Industries
February 3, 1981

1.3 SOLAR ENERGY UTILIZATION

Figures 5 and 6 show the use of solar energy and the percentage of losses for the liquid and air subsystems.

The liquid subsystem demonstrates good solar collection with approximately normal levels of transport losses. These losses occur from collector piping, TCL recirculating loop losses, and from storage tank losses. The liquid subsystem utilized 25% of the insolation made available and 67% of the collected energy.

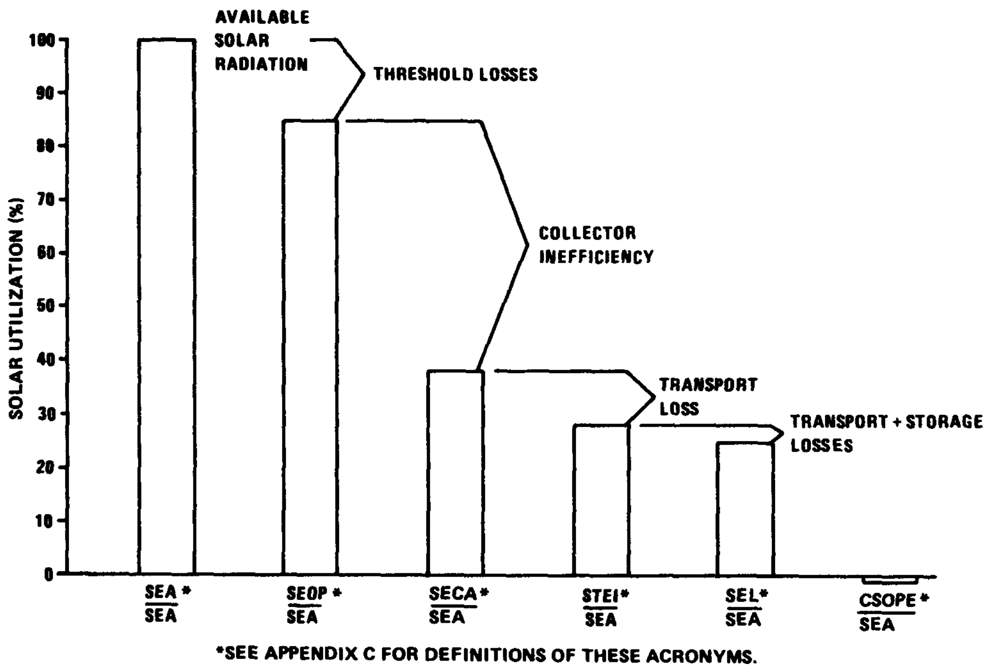

Figure 5. Solar Energy Use (Liquid Subsystem)
Oakmead Industries
October 1980 through May 1981

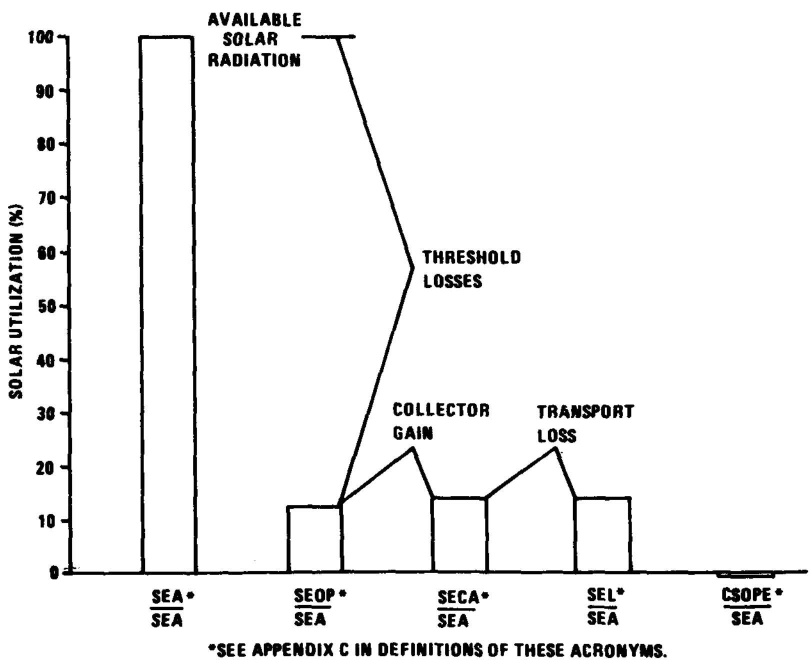

Figure 6. Solar Energy Use (Air Subsystem)
Oakmead Industries
October 1980 through May 1981

The air subsystem shows large threshold losses which are related to the significant passive gain through the south wall and problems with the collector controls. The passive gain reduced the load, and collector control problems delayed the operation of the fan due to a high set point. These two factors caused the large threshold loss. The figure shows a gain of one percent between operation incident energy and collected solar energy. This again is due to the south wall exhibiting some storage effects, and resulting in greater collected energy than energy incident on the collector array during these same times. There are no losses from collected energy to delivered energy since the losses in the ductwork are in the conditioned space.

1.4 SOLAR SYSTEM AVAILABILITY

The solar energy system at Oakmead Industries was operational during the entire reporting period except for the following:

- o On November 1 through November 14 the solar energy to space heating pump, P2, was off. The remaining system operated as expected.

The HVAC equipment operated well during the reporting period, providing the energy requirements of the building.

SECTION 2

SUBSYSTEM PERFORMANCE

2.1 COLLECTOR

2.1.1 LIQUID SUBSYSTEM PERFORMANCE

The Oakmead Industries solar site employs two types of collector arrays. The main collector array is a liquid flat-plate array which is utilized for DHW preheating, and for space heating for the north and south zones of the commercial building. The performance of the liquid collector is discussed below and presented in Table 3.

Table 3. LIQUID COLLECTOR SUBSYSTEM PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 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)
OCT	137.11	40.78E	30	108.82	37	5.61	0.60	28.92	27.97	79
NOV	104.63	37.76	36	84.34	45	0.56	0.85	25.96	33.05	71
DEC	95.08	38.15	40	90.90	42	0.00	1.39	30.85	30.46	64
JAN	78.30	29.96	38	74.66	40	0.00	1.45	22.32	25.72	61
FEB	105.84	47.86	45	95.64	50	0.00	0.86	40.02	34.31	67
MAR	115.55	51.37	45	108.25	48	0.00	1.30	41.40	33.26	65
APR	155.12	63.19	41	127.63	50	0.55	0.75	37.55	46.01	72
MAY	148.27	48.45	33	108.39	45	0.59	0.84	11.15	36.67	73
TOTAL	939.90	357.52	-	798.63	-	7.31	8.04	238.17	267.45	-
AVERAGE	117.49	44.69	38(1)	99.83	45(1)	0.91	1.01	29.77	33.43	69

E - Denotes estimated value.
(1) Weighted average.

The liquid-based collector array is composed of 116 Revere (two banks of 58 collectors each), Sun-Aid flat-plate collectors with a gross area of 2,622 square feet. The Sun-Aid collectors are single glazed with a selective surface. The collectors are oriented due south at a tilt of 45 degrees to the horizontal and are connected in a parallel series arrangement. The collectors are mounted on the north side facia of the concrete wall. A solution of 10% propylene glycol by weight in water is used as the transfer medium to the heat exchanger in the thermal control loop (TCL). The propylene glycol solution is circulated in the collector loop by collector pump P1 which is activated by the collector controller. A heat rejector dissipates excess collected energy for collector protection.

The controls were designed to activate the collector when the collector plate stagnation temperature was greater than 120°F. An adjustable time delay, nominally five minutes, maintained pump operation. At the end of the delay period, the collector pump would continue to operate if the plate temperature was 5°F greater than the TCL temperature. Otherwise, the pump would deactivate and the cycle will begin again. It should be noted that the TCL pump P3 operates in conjunction with the collector pump. This control device functioned extremely well until November 30 when the control device experienced problems and activated the collector pumps at night. Since November 30, the control device has not operated as well as before and system performance was degraded to a small degree. The control problem was corrected on March 25, but the controller operation was changed to function only on a temperature differential between collector plate temperature and TCL temperature.

During the eight-month period, there were 939.90 million BTU of solar energy incident on the liquid collector array. Of this total, 798.63 million BTU were incident while the collector loop was operating. The collector subsystem collected 357.52 million BTU, representing 38% of the total available insolation and 45% of the energy available during collector loop operation.

Solar energy collection required 8.04 million BTU of operating energy for collector pump P1, TCL pump P3, and heat rejector fan power. To prevent the collector subsystem from overheating, 7.31 million BTU of solar energy were rejected to the atmosphere.

The collector subsystem performed very well during the reporting period except for the times when the collector pump was activated all day long. This was caused by sporadic control problems which occurred between November 30 and March 25. Overall, the collector subsystem performed well and provided a solar contribution of 238.17 million BTU to the loads.

2.1.2 AIR COLLECTOR SUBSYSTEM PERFORMANCE

The air collector subsystem performance is discussed below and shown in Table 4. This subsystem provided solar heated air to the south zone of the commercial building.

The air-based south wall was incorporated as a novel, low cost addition to the original design. The configuration was based on a Trombe-type collection system. Vertical glazing was applied to the south wall and the wall was painted with a flat black paint. Interior building air enters through ports near the bottom of the glazing and gains energy as it passes upward in a two-inch gap between the glazing and the concrete wall. The heated air returns to the building interior via upper ports in the south wall and then enters a collector plenum. The collector plenum is connected with the south zone perimeter distribution system which provides space heating to the conditioned perimeter. (See System Description for additional details.)

Table 4. AIR COLLECTOR SUBSYSTEM PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 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 OPERATING ENERGY	SOLAR ENERGY DIRECTLY TO LOADS	DAYTIME AMBIENT TEMPERATURE (°F)
OCT	64.93	0.00	0	0.00	0	0.00	0.00	78
NOV	56.91	1.45	3	0.61	238	0.01	1.45	70
DEC	56.65	22.61	40	27.59	82	0.50	22.61	63
JAN	44.34	17.58	40	12.92	136	0.19	17.58	61
FEB	54.05	1.04	2	1.39	75	0.02	1.04	65
MAR	46.37	10.46	23	8.72	120	0.17	10.46	64
APR	45.44	2.94	7	2.61	113	0.06	2.94	72
MAY	34.29	0.01	0	0.02	38	0.00	0.01	74
TOTAL	402.98	56.09	-	53.86	-	0.95	56.09	-
AVERAGE	50.37	7.01	14(1)	6.73	104(1)	0.12	7.01	68

(1) Weighted average.

The south wall incorporates 78 panels or 1,675 square feet of vertical glazing (90-degree tilt) and consists of a double layer of low-iron, tempered glass. Air is used as the transport medium and the vertical wall behaves similar to a Trombe wall. Solar energy collection occurs when the temperature in the top of the air collectors is greater than 85°F and there is a demand for space heating. Solar energy collection terminates when the air collector temperature drops below 85°F or there is no heating demand.

During the reporting period, there were 402.98 million BTU of solar energy incident on the south wall. Of this total, 53.86 million BTU were incident while the air collector loop fan was operating. The collector subsystem absorbed 56.09 million BTU, representing 14% of the total available insolation and 104% of the energy available during the collector loop operation. Solar energy collection required 0.95 million BTU of operating energy for the south zone distribution fan. All of the collected solar energy entered the south zone heating perimeter.

The collector array operational efficiency of 104% is due to storage effects from the Trombe-type wall which results in the energy delivered being greater than the insolation level when the fan is operating. In fact, the south wall has demonstrated some passive gains into the south zone which was an added benefit to the solar system. The air collector subsystem operated well during the eight-month period, despite having a high set point for the fan activation.

2.2 STORAGE

The solar storage tank at Oakmead Industries is a 6,500-gallon steel tank with six inches of fiberglass insulation. Storage performance is depicted in Table 5. During the reporting period the energy delivered to storage was 267.45 million BTU while the energy removed from storage was 237.73 million BTU. The changed energy in the storage was -1.82 million. The resultant storage loss was 31.54 million BTU, which seems high. Flow meter W201 measures energy into and out of storage. This flow meter was installed near valve AV2 which modulates flow. This flow meter is not able to measure low flow rates and could have affected the high storage loss. Also during December, January, and March the energy removed from storage was greater than energy delivered to storage. This difference could be due to modulation effects that were not measured by flow meter W201.

The storage tank maintained an average temperature of 121°F and exhibited a storage efficiency of 88%. The storage subsystem performed well during the reporting period. (See Footnote 1.)

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1. Storage subsystem performance is evaluated by comparison of energy to storage, energy from storage, and the change in stored energy. The ratio of the sum of energy from storage and the change in stored energy, to the energy to storage is defined as storage efficiency. This relationship is expressed in the following equation:

$$STEFF = (STECH + STEO)/STEI$$

Where: STEFF = Storage efficiency

STECH = Change in stored energy

STEO = Energy removed from storage

STEI = Energy added to storage

Effective storage heat loss coefficient (c) for the storage subsystem can be defined as follows:

$$c = (STEI-STEO-STECH)/\left[(T_s - T_a) \times t\right] \frac{BTU}{hr\ °F}$$

Where: c = effective storage heat loss coefficient

T_s = average storage temperature

T_a = average ambient temperature in the vicinity of storage

t = number of hours in the month

Table 5. STORAGE PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMP. (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/hr °F)	LOSS FROM STORAGE
OCT	27.97	23.19	-2.16	75	157	0.62	6.94
NOV	33.05	28.56	-3.90	75	136	0.54	8.39
DEC	30.46	32.72	0.90	110	91	1.50	-3.16
JAN	25.72	30.00	1.40	122	86	2.42	-5.68
FEB	34.31	30.58	-2.08	83	110	0.68	5.81
MAR	33.26	33.71	0.74	104	96	2.37	-1.19
APR	46.01	30.92	3.33	74	139	0.52	11.76
MAY	36.67	28.05	-0.05	76	151	0.28	8.67
TOTAL	267.45	237.73	-1.82	-	-	-	31.54
AVERAGE	33.43	29.72	-0.23	88(1)	121	1.12	3.94

(1) Weighted average.

2.3 DOMESTIC HOT WATER (DHW)

The DHW subsystem performance for the Oakmead Industries solar site for the reporting period is depicted on Table 6 and graphically illustrated in Figure 7.

The actual hot water demand of 97.01 million BTU was satisfied by 41.14 million BTU of solar energy and 63.55 million BTU of auxiliary electrical energy. The hot water load of 104.69 million BTU includes a standby loss of 7.68 million BTU. The solar fraction of the load was 39% with a solar specific operating energy expense of 0.56 million BTU. The DHW subsystem provided an electrical energy savings of 40.58 million BTU. A daily average of 1,047 gallons of DHW was consumed at an average temperature of 112°F.

The DHW subsystem at Oakmead Industries uses a solar heated preheat tank in series with an electric DHW tank. (Refer to site schematic.) A very significant change in the DHW consumption profile was made in September 1980. A soldering type machine that requires hot water was attached to the DHW subsystem. The greater consumption of hot water significantly reduced the solar contribution in comparison to the original design figures. Since the design figures were not altered, it appears the DHW subsystem was poorer than expected. However, the DHW subsystem performed satisfactorily during the reporting period. Vitro Laboratories recommended the replacement of pump P4 to increase the solar energy contribution to the DHW subsystem. This replacement was delayed due to electrical installation problems.

Table 6. DOMESTIC HOT WATER SUBSYSTEM PERFORMANCE

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD	SOLAR FRACTION OF LOAD (%)	HOT WATER DEMAND	SOLAR FRACTION OF DEMAND (%)	SOLAR ENERGY USED	AUXILIARY THERMAL USED	AUXILIARY ELECT USED	OPERATING ENERGY	SUP. WATER TEMP (°F)	HOT WATER TEMP (°F)	HOT WATER CONSUMPTION (GAL)
OCT	18.82	68	15.85	66	12.82	6.00	6.00	0.15	68	115	41,263
NOV	13.45	54	12.32	54	7.30	6.15	6.15	0.09	67	117	29,272
DEC	11.08	11	10.48	11	1.20	9.88	9.88	0.03	63	106	29,470
JAN	10.39	5	9.94	5	0.54	9.85	9.85	0.02	62	100	31,491
FEB	11.98	26	11.83	25	3.10	8.88	8.88	0.07	63	112	29,028
MAR	11.80	15	10.98	14	1.78	10.02	10.02	0.04	65	103	34,595
APR	13.63	50	12.95	49	6.78	6.85	6.85	0.08	69	121	30,167
MAY	13.54	56	12.66	56	7.62	5.92	5.92	0.08	71	123	29,030
TOTAL	104.69	-	97.01	-	41.14	63.55	63.55	0.56	-	-	254,316
AVERAGE	13.09	39(1)	12.13	38	5.14	7.94	7.94	0.07	66	112	31,790

(1) Weighted average.

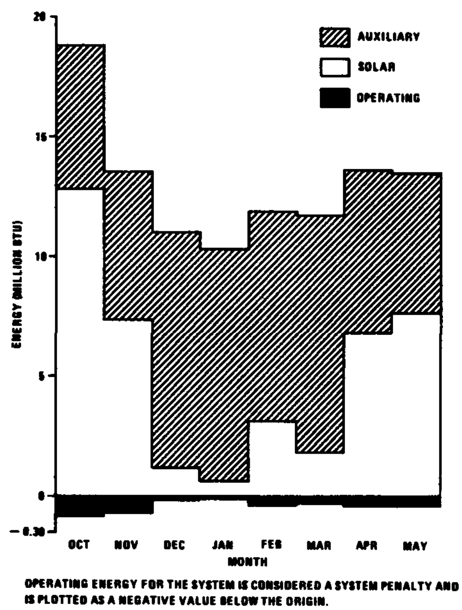

Figure 7. DHW Subsystem Performance
Oakmead Industries
October 1980 through May 1981

Two problems lowered the DHW subsystem performance. The DHW controller which activates pump P4 was 5°F-10°F too high. This decreased the potential solar contribution. Also, the DHW controller will not activate pump P4 unless the solar storage tank top temperature is greater than 100°F. The solar storage tank remained below 100°F during a large period of time, which resulted in the low solar contribution at these times. This low storage temperature coincides with the space heating periods which have priority over the DHW subsystem. Despite these problems, the DHW subsystem operated satisfactorily and provided 39% of the DHW load.

2.4 SPACE HEATING

The space heating performance for the Oakmead Industries solar site for the reporting period is shown in Tables 7 and 8 and presented graphically in Figure 8.

Table 7. SPACE HEATING SUBSYSTEM I

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	CONTROLLED DELIVERED ENERGY	TOTAL SOLAR ENERGY USED	TOTAL AUXILIARY THERMAL USED	SOLAR FRACTION OF LOAD (%)	BLDG TEMP (°F)	AMB TEMP (°F)
OCT	16.48	16.48	16.10	0.47	97	72E	68
NOV	46.38	46.38	20.11	26.27	43	72E	61
DEC	107.35	107.35	52.26	55.11	49	71E	57
JAN	96.87	96.87	39.36	57.51	41	70E	56
FEB	53.04	53.04	37.96	15.07	72	72E	60
MAR	79.35	79.35	50.08	29.34	63	70E	58
APR	38.63	38.63	33.71	5.03	87	I	62
MAY	3.79	3.79	3.54	0.25	93	I	64
TOTAL	441.89 (2)	441.89 (2)	253.12 (2)	189.05 (2)	-	-	-
AVERAGE	55.24	55.24	31.64	23.63	57 (1)	71E	61

E - Denotes estimated value (based upon return air from the building).
I - Denotes invalid data.
(1) - Weighted Average.
(2) - A minor software error caused the heating load to be not exactly equal to the sum of the solar energy used and the auxiliary thermal energy used. The average error is 0.06% and is insignificant.

Table 8. SPACE HEATING SUBSYSTEM II

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	MEASURED SOLAR ENERGY USED	SOLAR ENERGY LOSSES TO LOAD	TOTAL OPERATING ENERGY	SOLAR SPECIFIC OPERATING ENERGY	FOSSIL FUEL SAVINGS	AUXILIARY FOSSIL FUEL	HEATING DEGREE DAYS
OCT	16.48	16.10	0.00	6.42	0.10	26.83	0.78	33
NOV	46.38	20.11	0.00	6.92	0.22	33.52	43.78	150
DEC	107.35	52.26	0.00	8.67	0.40	87.10	91.86	257
JAN	96.87	39.36	0.00	8.63	0.34	65.60	95.85	283
FEB	53.04	37.96	0.00	6.21	0.42	63.27	25.13	147
MAR	79.35	50.08	0.00	8.39	0.42	83.47	48.91	216
APR	38.63	33.71	0.00	3.71	0.33	56.19	8.37	139
MAY	3.79	3.54	0.00	0.75	0.55	5.90	0.42	67
TOTAL	441.89	253.12	0.00	49.70	2.78	421.88	315.10	1,292
AVERAGE	55.24	31.64	0.00	6.21	0.35	52.74	39.39	162

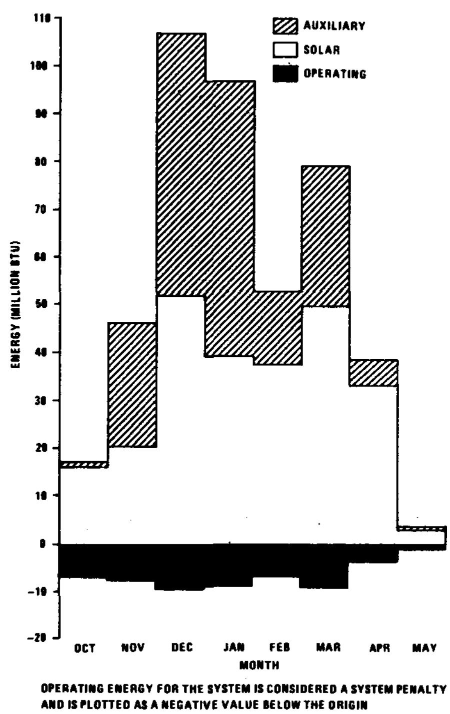

Figure 8. Space Heating Subsystem Performance
Oakmead Industries
October 1980 through May 1981

The space heating load of 441.89 million BTU was satisfied by 253.12 million BTU of solar energy and 189.05 million BTU of auxiliary thermal energy. The solar fraction of this load was 57%. The space heating subsystem used a total of 49.70 million BTU for operating energy.

During the reporting period, the space heating subsystem provided a fossil fuel savings of 421.88 million BTU, while incurring a solar specific electrical operating energy expense of 2.78 million BTU. The building temperature was estimated at approximately 71°F.

The space heating performance for the reporting period was good with solar supplying 57% of the total load. Solar energy was delivered for space heating by both the liquid and air collectors directly and from solar hot water storage. The space heating performance was lower partially due to collector control problems which removed energy from storage, and a problem with solar space heating pump P2 which remained off for the first 14 days during November. Overall, the space heating subsystem operated satisfactorily during the reporting period.

Oakmead Industries employs a unique recirculation loop between the liquid collector heat exchanger and the solar storage tank. This recirculation loop, designated as the thermal control loop (TCL), provides a connection between the heat exchanger, storage tank, and north and south space heating zones. As a result of this connection, the space heating subsystem is able to utilize energy from storage or energy directly from the collector loop. The TCL strives to maintain a constant 120°F water temperature to the space heating coils. Total control of this loop is accomplished by control valves AV1 and AV2. (See System Description for additional details.) This strategy tends to minimize losses and uses energy directly from the collector loop when available.

On April 14, 1981, the north zone solar space heating control began to operate continuously with the air handling unit time clock, despite no heating demand. A problem with the controller delivered solar energy to the north zone distribution system, but the fan was off and the dampers were closed. This energy was lost to the environment and is shown as a loss on the Energy Flow Diagram (Figure 2), from storage to space heating. It was necessary to estimate the building temperature because the sensor was not properly located. Building return air temperature was used as an estimate of the building temperature.

SECTION 3

OPERATING ENERGY

Measured monthly values of the solar specific operating energies for the Oakmead Industries solar system are presented in Table 9. Table 9 depicts the solar unique operating energy for each subsystem during the reporting period.

Table 9. SOLAR UNIQUE OPERATING ENERGY

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	DHW OPERATING ENERGY	SHS OPERATING ENERGY	TOTAL SOLAR UNIQUE OPERATING ENERGY
OCT	0.60	0.15	0.10	0.85
NOV	0.86	0.09	0.22	1.17
DEC	1.89	0.03	0.40	2.32
JAN	1.64	0.02	0.34	2.00
FEB	0.88	0.07	0.42	1.37
MAR	1.47	0.04	0.42	1.93
APR	0.81	0.08	0.33	1.22
MAY	0.84	0.08	0.55	1.47
TOTAL	8.99	0.56	2.78	12.33
AVERAGE	1.12	0.07	0.35	1.54

Operating energy is defined as the electrical energy required to support the functioning of the collector, storage, space heating, and DHW subsystems without directly affecting their thermal states. This energy is interpreted as pumping energy, fan power, and electrical power required to operate the entire solar system including those distribution fans in the conventional HVAC system.

At Oakmead Industries, the solar unique operating energy, that is used exclusively for the collection and delivery of solar energy, is classified in three subsystems. Pump P1, P3, heat rejector fan, and south fan operate the energy collection and storage subsystems, pump P2 operates the space heating subsystem, and pump P4 operates the DHW subsystem.

A total of 12.33 million BTU were consumed to operate the equipment which collect and deliver solar energy. In addition to the solar exclusive equipment, other fans were used to transport auxiliary energy in the HVAC system. The entire system used 59.25 million BTU of operating energy. The solar unique energy represents 21% of the total system operating energy.

SECTION 4

ENERGY SAVINGS

Energy savings for this site during the reporting period, are presented in Table 10. During this eight-month period, the solar system saved 28.81 million BTU of electrical energy and 421.88 million BTU of fossil fuel. These savings are equivalent to 8,436 kwh of electrical energy and 413,190 cubic feet (4,131.9 therms) of natural gas.

Table 10. ENERGY SAVINGS

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING SAVINGS ELECTRICAL	SPACE HEATING SAVINGS FOSSIL FUEL	DOMESTIC HOT WATER SAVINGS ELECTRICAL	ECSS OPERATING ENERGY	TOTAL NET ENERGY SAVINGS ELECTRICAL	TOTAL NET ENERGY SAVINGS FOSSIL FUEL
OCT	28.92	-0.10	26.83	12.67	0.60	11.97	26.83
NOV	27.41	-0.22	33.52	7.21	0.86	6.13	33.52
DEC	53.46	-0.40	87.10	1.17	1.89	-1.12	87.10
JAN	39.90	-0.34	65.60	0.52	1.64	-1.46	65.60
FEB	41.06	-0.42	63.27	3.03	0.88	1.73	63.27
MAR	51.86	-0.42	83.47	1.74	1.47	-0.15	83.47
APR	40.49	-0.33	56.19	6.70	0.81	5.56	56.19
MAY	11.16	-0.55	5.90	7.54	0.84	6.15	5.90
TOTAL	294.26	-2.78	421.88	40.58	8.99	28.81	421.88
AVERAGE	36.78	-0.35	52.74	5.07	1.12	3.60	52.74

Solar energy system savings are realized whenever energy provided by the solar energy system is used to meet system demands which would otherwise be met by auxiliary energy sources. The operating energy required to transport solar energy from the collector to storage is subtracted from the solar energy contribution to the loads to determine net savings.

The auxiliary energy sources for the space heating subsystem are two natural-gas-fired furnaces located in the north and south zones of the commercial building. The natural-gas-fired units are considered to be 60% efficient for computing energy savings.

The overall savings in dollars are approximately $2,095.90 for the eight-month period. The computed savings are based on an actual fuel rate at the site of $0.03 per kwh and 44.6 cents per therm of natural gas.

SECTION 5

WEATHER CONDITIONS

Oakmead Industries is located in Santa Clara, California at 37 degrees N latitude and 122 degrees W longitude.

Monthly values of the total solar energy incident in the plane of the liquid collector array and the average outdoor temperature measured at the site during the reporting period are presented in Table 11. Also presented in the table are the corresponding long-term average monthly values of the measured weather parameters. These long-term average weather data were obtained from nearby representative National Weather Service and SOLMET meteorological stations. The long-term average insolation values are total global horizontal radiation converted to collector angle and azimuth orientation. Table 12 represents the insolation values at a 90° tilt of the south wall.

Table 11. WEATHER CONDITIONS FOR LIQUID SUBSYSTEM

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 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
OCT	1,687	1,685	68	63	33	90	139	19
NOV	1,330	1,362	61	56	150	276	40	0
DEC	1,170	1,154	57	50	257	456	0	0
JAN	963	1,200	56	50	283	481	0	0
FEB	1,442	1,481	60	53	147	350	6	0
MAR	1,422	1,760	58	55	216	322	6	0
APR	1,972	1,895	62	58	139	228	48	12
MAY	1,824	1,872	64	62	67	123	32	20
TOTAL	11,810	12,409	-	-	1,292	2,326	271	51
AVERAGE	1,476	1,551	61	56	162	291	34	6

Note: Collector tilt 45°

During the period from October 1980 through May 1981, the average daily total incident solar radiation on the collector array was 1,476 BTU per square foot per day. This radiation was five percent below the estimated average daily solar radiation for this geographical area during the reporting period of 1,551 BTU per square foot per day for a south-facing plane with a tilt of 45

Table 12. SOUTH WALL INSOLATION (AIR COLLECTORS)

OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

MONTH	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/Ft^2-Day)
OCT	1,250
NOV	1,133
DEC	1,091
JAN	854
FEB	1,152
MAR	893
APR	904
MAY	660
TOTAL	7,937
AVERAGE	992

Note: Collector tilt 90°.

degrees to the horizontal. During the period, the highest monthly average insolation was 1,972 BTU per square foot per day during April and the lowest monthly average insolation was 963 BTU per square foot per day during January. The average ambient temperature during the reporting period was 61°F as compared with the long-term average of 56°F. The highest monthly average ambient temperature was 68°F during October, and the lowest monthly average ambient temperature was 56°F during January. The number of heating degree-days for the period (based on a 65°F reference) was 1,292 as compared with the long-term average of 2,326. The range of heating degree-days was from a high of 283 during January to a low of 33 during October. The number of cooling degree-days for the period was 271 as compared with the long-term average of 51.

The daily average ambient temperature was calculated using the same method as the National Weather Service (NWS). This method estimates the average temperature by averaging the daily maximum and minimum temperatures. The long-term weather data and reference data were recorded by the San Jose, California weather station.

Extraterrestrial radiation values are computed (see Footnote 1) and given in the table below for each month. The ratio of total insolation on a tilted surface to extraterrestrial radiation on a parallel surface is called the clearness index.

This parameter quantifies the effects of cloudiness and atmospheric transmission on the insolation received at the earth's surface. The clearness index ranged from a high of 64% during May to a low of 31% during January.

	MONTH							
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Extraterrestrial Insolation (BTU/Ft^2-Day)	3,288	3,146	3,036	3,115	3,285	3,326	3,110	2,830
TTL INS / EXT INS (%)	51	42	39	31	44	43	63	64

For a more complete set of meteorological data see Appendix E, which contains daily average values for the months of the reporting period.

1. Computation method given in "TRNSYS, a Transient Simulation Program," Engineering Experiment Station Report #38, Solar Energy Laboratory, University of Wisconsin, Madison.

SECTION 6

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 Solar 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, N.Y., 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, N.Y., 1977.

*6A. User's Guide to Monthly Performance Reports, June 1980, SOLAR/0004-80/18, 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, Oakmead Industries, October 1980, SOLAR/2076-80/10, Vitro Laboratories, Silver Spring, Maryland.

*8. Monthly Performance Report, Oakmead Industries, November 1980, SOLAR/2076-80/11, Vitro Laboratories, Silver Spring, Maryland.

*9. Monthly Performance Report, Oakmead Industries, December 1980, SOLAR/2076-80/12, 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 Renault and Handley Building, referred to as Oakmead Industries, is one of two nearly identical solar heated buildings located at the Oakmead Industrial Park, in Santa Clara, California. This commercial building contains approximately 60,000 square feet of floor area and is normally occupied six days a week, not including Sunday. The solar energy system installation is a retrofit and was originally designed to provide 85% of the annual heating requirements and 90% of the annual hot water demand. However, a significant new hot water load was added after the design projections. (Refer to Appendix F.)

The building has two central heating zones, one for the north zone of the building and the other for the south zone. The north zone heating system provides space heating for the central electronics area and for several offices. The north zone is heated by a combination of solar energy from a liquid-based flat-plate collector array and an auxiliary gas-fired furnace. The south zone heating system provides space heating for the warehouse area. The south zone is heated by a hybrid passive/active solar energy system installed on the south wall, solar energy from the liquid flat-plate collectors, and by an auxiliary gas-fired furnace.

Liquid-Based Solar Subsystem - The liquid-based solar collectors utilize a 10% by weight solution of propylene-glycol in water as the heat transfer medium for collecting solar energy. The flat-plate collector array faces due south at a tilt of 45° from the horizontal and employs a 2,622 square foot collector array. The collector surface is enhanced with a black chrome selective surface and a single layer of water white crystal glass.

The collector array is connected with storage and loads through the primary heat exchanger. The heat exchange step has been included so that positive, chemically-based freeze protection methods can be employed.

Energy removal from the heat exchanger is accomplished by means of a recirculation loop on the storage side. This loop, designated as a thermal control loop (TCL), provides a connection between the heat exchanger, storage tank, and north and south zones space heating subsystems. The thermal control loop strives to maintain a temperature between 120°F-125°F. Pump P3 maintains a constant flow of 45 gpm at the thermal control loop, while valve AV2 modulates flow in and out of the thermal control loop.

Valve AV2 acts in two modes. In the charge mode, when collected energy exceeds that of the building demand, valve AV2 modulates flow to and from the storage tank. When flow occurs to and from storage, valve AV1 provides makeup water by modulating flow from either the top or bottom of the tank to maintain 120°F in the TCL loop. This strategy maintains 120°F in the TCL and delivers solar energy to storage.

In the discharge mode, valve AV2 controls the rate of energy removal from the storage tank. The thermal control loop is maintained at the set point by appropriate additions of warm water from the top of the storage tank by valve

AV1. Energy additions to the loop are in response to the building heating loads as seen through HX2 and HX4 hot water coils. Pump P2 circulates water to these coils upon demand from the temperature control system. The thermal control loop logic provides a constant operating temperature for the hot water coils, while at the same time preventing unnecessary full flow conditions through the storage tank.

Other major components of the liquid-based subsystem include a storage tank, a heat rejection unit, and the domestic hot water system. The heat rejector unit dissipates excess solar energy when temperatures exceed the control set point. The storage tank stores the available energy in a 6,500-gallon insulated steel tank. A two-tank domestic hot water system will draw energy from the main storage system as necessary. A heat exchanger, HX6 located in a 120-gallon preheat tank, separates the potable water from the main storage tank fluid.

Air-Based South Wall Solar Subsystem - During final design of the building, it was decided to incorporate a novel, relatively low cost solar subsystem in the south wall. A major design objective was to arrive at a configuration adaptable to a Trombe-type collection system with little interference with the wall-casting procedure. The southern walls were modified to include inlet and outlet ports for air flow. The ports are spaced laterally on nine-foot centers and have a vertical spacing of nine feet.

The thickness of the concrete wall, 5.5 inches, is identical to that of the east and west walls. Because daytime heating is stressed at this site, the system deemphasizes the storage effects of the wall mass. (By way of comparison, a residential-based Trombe wall would be on the order of 18 inches thick.) The absorptivity of the wall surface has been enhanced with a field-applied black paint. Other design details include horizontal, perforated sheet metal strips to control lateral air flow, and a field-installed glazing system. The glazing system consists of a double layer of low-iron, tempered glass attached with standard concrete fasteners, and flashing details. A six-foot overhang shades the vertical collector system during the summer seasons.

During operation, return air is drawn into the south wall system via the lower registers. The air rises within the two-inch gap formed between the wall and glazing. Flow is induced, in part, by natural thermosiphon effects, and in part, by a slight vacuum created in the perimeter duct distribution system. The heated air returns to the building interior via the upper ports and then enters a collection plenum. The collection plenum is, in turn, connected to the south perimeter distribution system. Discharge air from the south wall can be further conditioned by a hot water coil, HX4, supplied by the liquid-based solar subsystem. An auxiliary duct-mounted gas heater serves to meet demand in the event that the combined efforts of the solar subystems are insufficient to meet the load.

The manufacturers of the major solar system equipment and components are listed on the following page.

Equipment/Components	Manufacturer	Model Number
Collectors	Revere	Sun-Aid
Heat Rejector Unit	American Standard	Fanex 224
Heat Exchanger	Bell & Gossett	Shell + Tube WU-128-44
Preheat Tank	Buffalo	-
DHW Tank	National	-
Storage Tank	Saracco Mfg.	Custom Made
Valves (AV1 & AV2)	Stafa Control System AG	-
Controls	Stafa Control System AG	-
Pump P1	Bell & Gossett	1522-1½ AAB
Pump P2	Bell & Gossett	60-1½ AA
Pump P3	Bell & Gossett	60-1½ AA
Pump P4	Grundfos	UP-25-42SF

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

Mode 1 - Liquid Collector Subsystem-to-Thermal Control Loop - In this mode, collector loop pump P1 starts if the collector plate stagnation temperature is greater than 120°F. An adjustable time delay relay, provides an off delay for pump P1 (normally five minutes). At the end of the delay period, pump P1 will continue to operate if the collector plate temperature is 5°F greater than the thermal control loop temperature. Pump P3 is interlocked with pump P1 to provide constant operation of collector to thermal control loop. Pumps P1 and P3 are deactivated when the differential temperature between the collector plate and the thermal control loop falls below 5°F.

Mode 2 - Liquid Collector Subsystem Protection - If the collector plate temperature exceeds 240°F or the top of the storage tank is greater than 200°F, valve AV3 connects the solar loop to the heat rejector, energizes the heat rejector fan, de-energizes pump P3, and energizes pump P1. This provides collector protection from extremely high temperatures. This mode is deactivated when the plate temperature falls below 240°F or the storage tank falls below 200°F.

Mode 3 - Thermal Control Loop-to-Storage (Liquid Subsystem) - In this mode, solar energy is transferred to storage when the thermal control loop temperature exceeds 120°F. Valve AV2 modulates flow to and from storage while valve AV1 provides makeup water from the top or bottom of the storage tank. This mode is completely controlled by the operation of valves AV1 and AV2.

Mode 4 - Thermal Control Loop-to-Space Heating (Liquid Subsystem) - This mode is energized when there is a demand for space heating. Pump P2 is interlocked to operate with pump P3 if the TCL temperature is greater than 80°F or the storage tank top temperature is greater than 80°F. Solar energy is provided to the north and south space heating zones until there is no demand for space heating or the temperature in the TCL and storage tank falls below 80°F.

Mode 5 - Storage-to-DHW Subsystem (Liquid Subsystem) - In this mode, solar energy is transferred from the storage tank to the DHW preheat tank if the DHW preheat tank is less than 160°F, storage tank is greater than 100°F, and the storage tank temperature is 10°F greater than the DHW preheat tank. Pump P4 is activated to deliver energy to the DHW system and deactivates when the difference between the storage tank temperature and the DHW preheat tank falls below 5°F.

Mode 6 - Auxiliary Space Heating (Liquid and Air Subsystems) - This mode activates when there is a need for space heating and solar energy is insufficient to meet the demand. The auxiliary gas-fired furnace will provide the remaining building space heating demand. (There are two gas-fired furnaces for the north and south heating zones.)

Mode 7 - Auxiliary Hot Water Heating (Liquid Subsystem) - In this mode, auxiliary hot water is provided by an electric heater. If solar energy is insufficient, then the electric hot water heater provides auxiliary energy upon demand. The DHW tank is maintained at a control set point of approximately 140°F.

Mode 8 - Air Collector Subsystem-to-Space Heating - This mode activates when there is a need for space heating in the south zone only. If the temperature in the air collectors is greater than 85°F, then the fan in the auxiliary furnace will activate to deliver heated air to the south zone. This mode is deactivated when the temperature in the air collectors falls below 85°F or there is no space heating demand in the south zone. (The return plenum damper is closed during the summer months.)

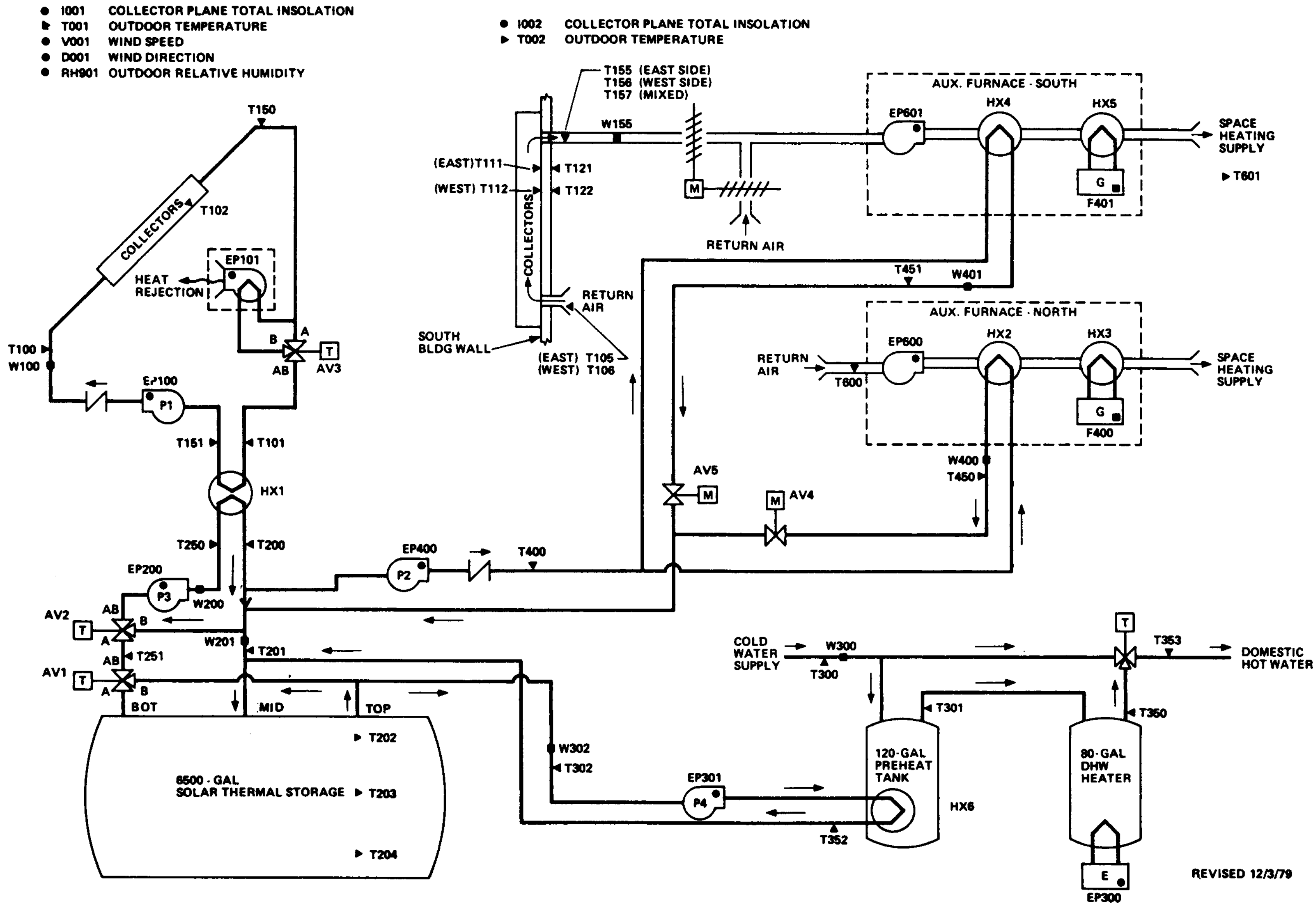

Figure A-1. Oakmead Industries Solar Energy System Schematic

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

The performance of the Oakmead Industries 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.

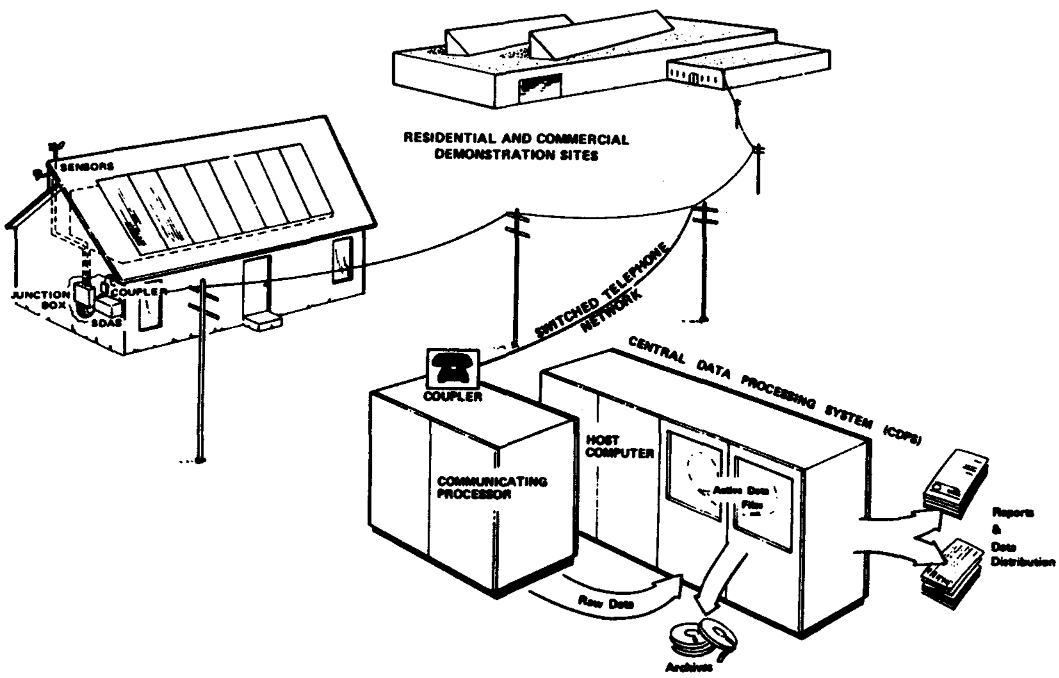

Figure B-1. The National Solar Data Network

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 the system and has the SDAS transmit the data on the cassette tape back to the 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 0-1,023. 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.

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 realtime 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 Oakmead Industries solar energy system from October 1980 through May 1981 was analyzed during the year, and Monthly Performance Reports were published through December 1980 for the months when sufficient valid data were available. See the following page for a list of these reports.

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

OTHER DATA REPORTS ON THIS SITE*

Monthly Performance Reports:

October 1980, SOLAR/2076-80/10
November 1980, SOLAR/2076-80/11
December 1980, SOLAR/2076-80/12

* These reports can be obtained (free) by contacting: U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.

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	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 above 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 below 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:

$$\frac{T_i - T_a}{I} \quad \frac{°F \times hr. \times sq.\ ft.}{BTU}$$

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 x 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

OAKMEAD INDUSTRIES

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

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

where I001 is the solar radiation measurement provided by the pyranometer in BTU per square foot per hour, AREA 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 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 specific heat 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 (°F)

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

AVERAGE BUILDING TEMPERATURE (°F)

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

DAYTIME AVERAGE AMBIENT TEMPERATURE (°F)

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

for ± three hours from solar noon

OUTDOOR RELATIVE HUMIDITY (%)

$$RELH = (1/60) \times \Sigma\ RH901 \times \Delta\tau$$

WIND VELOCITY (MPH)

$$WIND = (1/60) \times \Sigma\ V001 \times \Delta\tau$$

WIND DIRECTION (DEG)

$$WDIR = D001$$

LIQUID COLLECTOR SUBSYSTEM

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

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

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 - LIQUID SYSTEM (BTU)

$$SECA = \Sigma \, [M100 \times CP \, (T150 - T100)] \times \Delta\tau$$

REJECTED SOLAR ENERGY (BTU)

$$CSRJE = \Sigma \, [M100 \times CP \times (T150 - T101)] \times \Delta\tau$$

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

$$CLEFOP = SECA/SEOP$$

ECESS OPERATING ENERGY (BTU)

$$CSOPE = 56.8833 \times \Sigma \, (EP100 + EP101 + EP200) \times \Delta\tau$$

AIR COLLECTOR SUBSYSTEM

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

$$SE = (1/60) \times \Sigma \, I002 \times \Delta\tau$$

OPERATIONAL INCIDENT SOLAR ENERGY (BTU)

$$SEOP = (1/60) \times \Sigma \, [I002 \times CLAREA] \times \Delta\tau$$

when the collector loop is activated

HUMIDITY RATIO FUNCTION (BTU/lb_m - F)

$HRF = 0.24 = 0.444 \times HR$

where 0.24 is the specific heat and HR is the humidity ratio of the transport air. This function is used whenever the humidity ratio will remain constant as the transport air flows through a heat exchanging device.

COLLECTED SOLAR ENERGY (BTU)

$SECA = \Sigma \, [M155 \times HRF \, (T157 - (T105 + T106/2))] \times \Delta\tau$

ECSS OPERATING ENERGY (BTU)

$CSOPE = 56.8833 \times \Sigma \, EP601 \times \Delta\tau$

when collector loop is activated

INDICENT SOLAR ENERGY ON COLLECTOR ARRAY (BTU)

$SEA = SE \times CLAREA$

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

$SEC = SECA/CLAREA$

COLLECTOR ARRAY EFFICIENCY

$CLEF = SECA/SEA$

COLLECTOR ARRAY OPERATION EFFICIENCY

$CLEFOP = SECA/SEOP$

<u>STORAGE SUBSYSTEM</u>

AVERAGE TEMPERATURE OF STORAGE (°F)

$TST = (1/60) \times \Sigma \, [(T202 + T203 + T204)/3] \times \Delta\tau$

SOLAR ENERGY TO STORAGE (BTU)

$STEI = \Sigma \, [M201 \times CP \times (T201 - T251)] \times \Delta\tau$

when $T201 > T251$

SOLAR ENERGY FROM STORAGE (BTU)

$STEO = \Sigma \, [M201 \times CP \times (T251 - T201)] \times \Delta\tau$

when $T251 > T201$

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 (%)

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

EFFECTIVE HEAT TRANSFER COEF (BTU/°F-FT²-HR)

$$STPER = (1/60) \times \Sigma\ [SUR\_AREA \times (TST - AMB)] \times \Delta\tau$$

SUR_AREA = storage tank surface area
AMB = temperature surrounding storage tank

DHW SUBSYSTEM

HOT WATER SUBSYSTEM OPERATING ENERGY (BTU)

$$HWOPE = 56.8833 \times \Sigma\ EP301 \times \Delta\tau$$
$$HWOPE1 = 56.8833 \times \Sigma\ EP301 \times \Delta\tau$$

STORAGE ENERGY TO HOT WATER SUBSYSTEM (BTU)

$$HWSE = \Sigma\ [M302 \times CP \times (T302 - T352)] \times \Delta\tau$$

HOT WATER SUBSYSTEM AUXILIARY ELECTRICAL ENERGY (BTU)

$$HWAE = 56.8833 \times \Sigma\ EP300 \times \Delta\tau$$

HOT WATER SUBSYSTEM AUXILIARY THERMAL ENERGY (BTU)

$$HWAT = HWAE$$

HOT WATER SUBSYSTEM DEMAND (BTU)

$$HWDM = \Sigma\ M300 \times CP \times (T353 - T300)$$

HOT WATER LOAD (BTU)

$$HWL = HWAT + HWSE$$

HOT WATER SUBSYSTEM SOLAR FRACTION (PERCENT)

$$HWSFR = 100 \times HWSE/(HWSE + HWAT)$$

HOT WATER SUBSYSTEM ELECTRICAL ENERGY SAVINGS (BTU)

$$HWSVE = HWSE - HWOPE1$$

HOT WATER CONSUMED (GAL)

$$HWSCM = \Sigma\ W300$$

SUPPLY COLD WATER TEMPERATURE (°F)

$$TSW = (M300 \times T300)/M300$$

IF M300 = 0 then TSW = TWS_P

SUPPLY HOT WATER TEMPERATURE (°F)

$$THW = (M300 \times T353)/M300$$

if M300 = 0 then THW = THW_P

HOT WATER DEMAND SOLAR FRACTION (BTU)

$$TANKV = HWCAP \times [(RHO(THW) \times CP(THW) \times THW - RHO\ (TSW) \times CP\ (TSW) \times TSW]$$

$$TEMP = EXP\ [-(HWAT + HWSE)/TANKV]$$

$$HWDSFR = [HWSE/(HWSE + HWAT)] \times (1 - TEMP) + HWDSFR\_P/100) \times TEMP$$

(HWDSFR_P => Past value of HWDSFR)

SPACE HEATING SUBSYSTEM

SPACE HEATING SUBSYSTEM OPERATING ENERGY (BTU)

$$HOPE = [56.8833 \times \Sigma\ (EP400 + EP600 + EP601)] \times \Delta\tau$$
$$HOPE1 = [56.8833 \times \Sigma\ EP400] \times \Delta\tau$$

SOLAR ENERGY TO SPACE HEATING SUBSYSTEM (BTU)

$$HSE = \Sigma\ [M400 \times CP \times (T400 - T450)] \times \Delta\tau + \Sigma\ [M401 \times CP \times (T400 - T451)] \times \Delta\tau + SECA\ (AIR\ SYSTEM)$$

SPACE HEATING AUX FOSSIL ENERGY (BTU)

$$HAF = \Sigma\ (F400 + F401) \times NGC$$

$$NGC = 1{,}021\ BTU/ft^2$$

SPACE HEATING AUX THERMAL ENERGY (BTU)

$$HAT = HAF \times 0.6$$

SPACE HEATING LOAD (BTU)

CDE = HSE + HAT

EQUIPMENT HEATING LOAD (BTU)

EHL = CDE

SPACE HEATING SOLAR FRACTION (PERCENT)

HSFR = 100 x HSE/(HSE + HAT)

SPACE HEATING FOSSIL SAVINGS (BTU)

HSVF = HSE/0.6

SPACE HEATING ELECTRICAL SAVINGS

HSVE = -HOPE 1

<u>SYSTEM FACTORS</u>

SOLAR ENERGY TO LOADS

CSEO = HWSE + HSE

SOLAR ENERGY USED

SEL = CSEO

ECSS SOLAR CONVERSION EFFICIENCY

CSCEF = SEL/SEA (TOTAL)

SYSTEM LOAD

SYSL = HWL + EHL

SYSTEM SOLAR FRACTION

SFR = (HWSFR x HWL + HSFR x EHL)/SYSL

SYSTEM OPERATING ENERGY

SYSOPE = HWOPE + CSOPE + HOPE

SYSTEM AUX FOSSIL ENERGY

AXF = HAF

SYSTEM AUX THERMAL ENERGY

AXT = HAT + HWAT

SYSTEM AUX ELECTRICAL ENERGY

AXE = HWAE

SYSTEM ELECTRICAL SAVINGS

TSVE = HSVE + HWSVE - CSOPE (TOTAL)

SYSTEM FOSSIL SAVINGS

TSVF = HSVF

TOTAL ENERGY CONSUMED

TECSM = SECA + SYSOPE + AXF + AXE

SYSTEM PERFORMANCE FACTOR

SYSPF = SYSL/[AXF + 3.33 x (AXE + SYSOPE)]

APPENDIX E

METEOROLOGICAL CONDITIONS

The following tables include monthly environmental data from October 1980 through May 1981. Also included is the long-term weather data for the site.

The relative humidity sensor, wind speed, and wind direction sensors were reporting incorrect data during the reporting period. This data was invalidated as shown in the monthly weather tables.

OAKMEAD INDUSTRIES LONG-TERM WEATHER DATA

COLLECTOR TILT: 45 DEGREES
LATITUDE: 37 DEGREES

LOCATION: SANTA CLARA, CALIFORNIA
COLLECTOR AZIMUTH: 0 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
OCT	2,088	1,213	0.58105	1.389	1,685	90	19	63
NOV	1,574	822	0.52246	1.656	1,362	276	0	56
DEC	1,344	645	0.48017	1.788	1,154	456	0	50
JAN	1,469	708	0.48177	1.696	1,200	481	0	50
FEB	1,922	1,018	0.52933	1.456	1,481	350	0	53
MAR	2,497	1,456	0.58332	1.208	1,760	322	0	55
APR	3,079	1,921	0.62385	0.987	1,895	228	12	58
MAY	3,477	2,212	0.63621	0.846	1,872	123	20	62

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 of heating degrees-days per month.

CDD - Number of cooling degrees-days per month.

TBAR - Average ambient temperature in degrees Fahrenheit.

MONTHLY REPORT: OAKMEAD INDUSTRIES
OCTOBER 1980
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	1967	81	101	I	I	I
2	2028	81	102	I	I	I
3	2083	79	98	I	I	I
4	2008	72	87	I	I	I
5	1677	67	80	I	I	I
6	1602	68	78	I	I	I
7	1929	71	88	I	I	I
8	2031	70	87	I	I	I
9	1796	65	81	I	I	I
10	1493	61	70	I	I	I
11	822	59	66	I	I	I
12	1480	62	75	I	I	I
13	775	58	67	I	I	I
14	1750	58	66	I	I	I
15	2037	60	73	I	I	I
16	1922	59	76	I	I	I
17	1951	61	77	I	I	I
18	1964	61	77	I	I	I
19	1944	62	78	I	I	I
20	1884	63	80	I	I	I
21	1817	64	79	I	I	I
22	1808	65	80	I	I	I
23	1826	64	85	I	I	I
24	1008	59	67	I	I	I
25	366	58	63	I	I	I
26	1987	59	76	I	I	I
27	1874	60	72	I	I	I
28	1848	63	81	I	I	I
29	1839	63	80	I	I	I
30	1072	61	74	I	I	I
31	1702	62	80	I	I	I
SUM	52291	-	-	-	-	-
AVG	1687	64	79	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
NOVEMBER 1980
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	766	58	68	I	I	I
2	1819	63	81	I	I	I
3	1528	65	76	I	I	I
4	1812	68	89	I	I	I
5	802	59	66	I	I	I
6	1465	62	75	I	I	I
7	854	63	72	I	I	I
8	1820	61	72	I	I	I
9	1886	57	71	I	I	I
10	953	57	67	I	I	I
11	932	55	67	I	I	I
12	1649	53	70	I	I	I
13	1843	53	71	I	I	I
14	1823	55	74	I	I	I
15	1821	58	70	I	I	I
16	1352	54	69	I	I	I
17	1649	58	73	I	I	I
18	1752	58	75	I	I	I
19	1202	61	71	I	I	I
20	939	70	84	I	I	I
21	372	57	57	I	I	I
22	947	60	69	I	I	I
23	796	56	62	I	I	I
24	1907	56	66	I	I	I
25	1452	54	69	I	I	I
26	1703	54	71	I	I	I
27	1635	55	74	I	I	I
28	1625	55	75	I	I	I
29	636	53	60	I	I	I
30	165	52	56	I	I	I
SUM	39904	-	-	-	-	-
AVG	1330	58	71	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
DECEMBER 1980
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	606	52	62	I	I	I
2	221	58	62	I	I	I
3	83	55	55	I	I	I
4	1431	55	60	I	I	I
5	1692	51	63	I	I	I
6	1776	49	62	I	I	I
7	1834	48	61	I	I	I
8	1763	50	65	I	I	I
9	1520	48	66	I	I	I
10	1670	48	66	I	I	I
11	1692	49	67	I	I	I
12	1526	48	66	I	I	I
13	1512	49	68	I	I	I
14	1508	50	68	I	I	I
15	1642	56	77	I	I	I
16	1585	56	76	I	I	I
17	921	55	68	I	I	I
18	611	54	62	I	I	I
19	1256	56	68	I	I	I
20	1243	55	68	I	I	I
21	94	54	59	I	I	I
22	746	55	60	I	I	I
23	633	52	57	I	I	I
24	974	53	63	I	I	I
25	814	54	63	I	I	I
26	1355	54	69	I	I	I
27	682	52	57	I	I	I
28	1553	55	70	I	I	I
29	1016	50	60	I	I	I
30	1109	49	58	I	I	I
31	1194	47	58	I	I	I
SUM	36261	-	-	-	-	-
AVG	1170	52	64	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
JANUARY 1981
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	1454	47	61	I	I	I
2	428	45	51	I	I	I
3	725	55	65	I	I	I
4	1761	55	67	I	I	I
5	1696	54	70	I	I	I
6	1579	50	64	I	I	I
7	568	46	52	I	I	I
8	906	49	60	I	I	I
9	748	48	54	I	I	I
10	1362	47	61	I	I	I
11	931	47	55	I	I	I
12	352	51	56	I	I	I
13	1391	54	72	I	I	I
14	1242	55	70	I	I	I
15	1052	56	66	I	I	I
16	1327	59	67	I	I	I
17	474	59	64	I	I	I
18	1192	59	73	I	I	I
19	676	61	66	I	I	I
20	396	60	64	I	I	I
21	181	59	62	I	I	I
22	70	57	56	I	I	I
23	542	51	55	I	I	I
24	1551	52	65	I	I	I
25	1878	50	62	I	I	I
26	139	47	48	I	I	I
27	96	52	52	I	I	I
28	662	52	58	I	I	I
29	626	48	50	I	I	I
30	1888	51	63	I	I	I
31	1970	49	65	I	I	I
SUM	29864	-	-	-	-	-
AVG	963	52	61	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
FEBRUARY 1981
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	1657	50	65	I	I	I
2	1783	54	68	I	I	I
3	1837	53	71	I	I	I
4	1682	55	69	I	I	I
5	1588	53	69	I	I	I
6	1553	54	67	I	I	I
7	443	53	59	I	I	I
8	100	50	51	I	I	I
9	1265	54	60	I	I	I
10	1240	55	66	I	I	I
11	1410	59	68	I	I	I
12	1467	60	74	I	I	I
13	463	61	64	I	I	I
14	1720	62	72	I	I	I
15	1647	58	70	I	I	I
16	1594	59	72	I	I	I
17	1360	61	72	I	I	I
18	1930	63	77	I	I	I
19	950	58	65	I	I	I
20	2212	58	66	I	I	I
21	2175	63	79	I	I	I
22	2082	61	78	I	I	I
23	1943	59	73	I	I	I
24	1868	52	58	I	I	I
25	1049	48	59	I	I	I
26	1090	50	57	I	I	I
27	1926	55	66	I	I	I
28	330	51	52	I	I	I
SUM	40367	-	-	-	-	-
AVG	1442	56	67	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
MARCH 1981
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	444	52	57	I	I	I
2	1656	56	67	I	I	I
3	324	54	58	I	I	I
4	192	49	49	I	I	I
5	2000	52	60	I	I	I
6	2104	56	72	I	I	I
7	1653	57	84	I	I	I
8	1947	60	74	I	I	I
9	2097	61	77	I	I	I
10	2086	58	71	I	I	I
11	1578	60	70	I	I	I
12	510	55	59	I	I	I
13	1603	52	58	I	I	I
14	1657	56	67	I	I	I
15	165	51	54	I	I	I
16	2178	55	66	I	I	I
17	1696	59	71	I	I	I
18	258	52	54	I	I	I
19	626	53	57	I	I	I
20	394	49	51	I	I	I
21	1582	58	69	I	I	I
22	1056	58	67	I	I	I
23	1766	56	68	I	I	I
24	1296	59	72	I	I	I
25	944	58	65	I	I	I
26	1968	53	61	I	I	I
27	2228	57	68	I	I	I
28	2244	60	76	I	I	I
29	1480	55	62	I	I	I
30	2279	55	65	I	I	I
31	2061	55	67	I	I	I
SUM	44071	-	-	-	-	-
AVG	1422	56	65	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
APRIL 1981
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	2048	54	63	I	I	I
2	2212	55	66	I	I	I
3	2265	56	71	I	I	I
4	2270	60	75	I	I	I
5	2218	61	76	I	I	I
6	2243	58	70	I	I	I
7	2187	57	71	I	I	I
8	2206	55	66	I	I	I
9	2210	56	68	I	I	I
10	2202	54	66	I	I	I
11	2270	53	64	I	I	I
12	2232	55	69	I	I	I
13	2229	61	80	I	I	I
14	2157	59	76	I	I	I
15	2086	57	68	I	I	I
16	1895	61	75	I	I	I
17	1704	59	68	I	I	I
18	184	54	55	I	I	I
19	560	53	58	I	I	I
20	1935	58	67	I	I	I
21	2080	60	72	I	I	I
22	2155	69	86	I	I	I
23	2110	64	75	I	I	I
24	2045	60	71	I	I	I
25	1005	55	61	I	I	I
26	2175	55	64	I	I	I
27	2179	61	73	I	I	I
28	2137	74	90	I	I	I
29	2082	78	94	I	I	I
30	1880	70	85	I	I	I
SUM	59162	-	-	-	-	-
AVG	1972	59	72	I	I	I

I - INVALID DATA.

MONTHLY REPORT: OAKMEAD INDUSTRIES
MAY 1981
ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ. FT (Q001)	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	2103	63	75	I	I	I
2	2149	58	70	I	I	I
3	2041	58	72	I	I	I
4	2126	57	69	I	I	I
5	2026	58	70	I	I	I
6	2073	59	70	I	I	I
7	2105	60	75	I	I	I
8	2051	63	77	I	I	I
9	2077	63	74	I	I	I
10	2093	62	76	I	I	I
11	2054	69	87	I	I	I
12	2007	63	77	I	I	I
13	1960	62	74	I	I	I
14	1446	59	69	I	I	I
15	1534	59	67	I	I	I
16	2107	59	68	I	I	I
17	1385	61	71	I	I	I
18	730	59	62	I	I	I
19	731	55	60	I	I	I
20	2031	58	72	I	I	I
21	1469	59	68	I	I	I
22	2015	62	73	I	I	I
23	1989	64	75	I	I	I
24	1785	65	75	I	I	I
25	771	66	72	I	I	I
26	1798	65	83	I	I	I
27	1959	64	75	I	I	I
28	1888	63	75	I	I	I
29	1972	63	70	I	I	I
30	2039	63	72	I	I	I
31	2032	65	81	I	I	I
SUM	56549	-	-	-	-	-
AVG	1824	61	73	I	I	I

I - INVALID DATA.

APPENDIX F

SITE HISTORY, PROBLEMS, CHANGES IN SOLAR SYSTEM

Oakmead Industries is a commercial building that is usually occupied six days a week throughout the year. The building is a retrofit design, but a sloping north facia was included in the building design as a future possibility for a solar energy system. The building is a modern concrete structure with north facing glazing to enhance the building appearance. (Refer to site pictures.) The building interior includes an office space, manufacturing area, and a warehouse area with a total building area of 60,000 square feet.

Only minor problems occurred during the October 1980 through May 1981 reporting period. These included liquid collector control problems, improper building time clock set points for the north zone heating distribution subsystem, control problems with the solar DHW preheating mode, and a pump P2 failure for the first 14 days in November. Otherwise, the solar and auxiliary system operated well throughout the reporting period.

The DHW consumption pattern was altered but the design solar fraction was not ammended. Vitro Laboratories recommended that pump P4 be replaced with a larger pump to increase the solar contribution to the DHW subsystem. However, the replacement has been delayed due to the complexity of the required changes. The increased DHW usage has lowered the actual solar fraction from the design expectations. The change in DHW consumption was introduced by using DHW for a soldering-type machine. A plumbing change was made to utilize hot water from the DHW subsystem.

APPENDIX G

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 H

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 (NON-TOTALIZING)

The Ramapo Mark V strain gauge flow meters are used for the measurement of liquid flow. The flow meters sense the flow of the liquids by measuring the force exerted by the flow on a target suspended in the flow stream. This force is transmitted to a four active arm strain gauge bridge to provide a signal proportional to flow rate squared. The flow meters are available in a screwed end configuration, a flanged configuration, and a wafer configuration. Each flow meter is calibrated for the particular fluid being used in the application.

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: APRIL 1981

SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM

GENERAL SITE DATA:	CONVENTIONAL UNITS
INCIDENT SOLAR ENERGY	200.558 MILLION BTU
	N.A. BTU/SQ.FT.
COLLECTED SOLAR ENERGY	66.134 MILLION BTU
	N.A. BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	N.A. DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.20
ECSS OPERATING ENERGY	0.811 MILLION BTU
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	4.658 MILLION BTU
TOTAL ENERGY CONSUMED	85.937 MILLION BTU

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	13.631	38.666	N.A.	52.300 MILLION BTU
SOLAR FRACTION	50	87	N.A.	77 PERCENT
SOLAR ENERGY USED	6.780	33.717	N.A.	40.496 MILLION BTU
OPERATING ENERGY	0.081	3.765	N.A.	4.658 MILLION BTU
AUX. THERMAL ENERGY	6.851	5.024	N.A.	11.872 MILLION BTU
AUX. ELECTRIC FUEL	6.851	N.A.	N.A.	6.851 MILLION BTU
AUX. FOSSIL FUEL	N.A.	8.373	N.A.	8.373 MILLION BTU
ELECTRICAL SAVINGS	6.699	-0.334	N.A.	5.553 MILLION BTU
FOSSIL SAVINGS	N.A.	56.195	N.A.	56.195 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.12

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.09

* = 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: APRIL 1981
SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	200.558 MILLION BTU
	N.A. BTU/SQ.FT.
COLLECTED SOLAR ENERGY	66.134 MILLION BTU
	N.A. BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	61 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.330
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	N.A.
AVERAGE AMBIENT TEMPERATURE	N.A. DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.20
ECSS OPERATING ENERGY	0.811 MILLION BTU
ECSS PERFORMANCE FACTOR	9424 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	4.658 MILLION BTU
TOTAL ENERGY CONSUMED	85.937 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	674 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	198 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	13.631	38.666	N.A.	52.300 MILLION BTU
SOLAR FRACTION	50	87	N.A.	77 PERCENT
SOLAR SAVINGS RATIO	N.A.	N.A.	N.A.	N.A.
SOLAR ENERGY USED	6.780	33.717	N.A.	40.496 MILLION BTU
OPERATING ENERGY	0.081	3.765	N.A.	4.658 MILLION BTU
AUX. THERMAL ENERGY	6.851	5.024	N.A.	11.872 MILLION BTU
AUX. ELECTRIC FUEL	6.851	N.A.	N.A.	6.851 MILLION BTU
AUX. FOSSIL FUEL	N.A.	8.373	N.A.	8.373 MILLION BTU
ELECTRICAL SAVINGS	6.699	-0.334	N.A.	5.553 MILLION BTU
FOSSIL SAVINGS	N.A.	56.195	N.A.	56.195 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.09

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MONTHLY REPORT: APRIL 1981

SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM

	SI UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	211.589 GIGA JOULES
	N.A. KJ/SQ.M.
COLLECTED SOLAR ENERGY	69.772 GIGA JOULES
	N.A. KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	N.A. DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.20
ECSS OPERATING ENERGY	0.856 GIGA JOULES
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	4.914 GIGA JOULES
TOTAL ENERGY CONSUMED	90.663 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	14.381	40.792	N.A.	55.177 GIGA JOULES
SOLAR FRACTION	50	87	N.A.	77 PERCENT
SOLAR ENERGY USED	7.153	35.571	N.A.	42.724 GIGA JOULES
OPERATING ENERGY	0.086	3.972	N.A.	4.914 GIGA JOULES
AUX. THERMAL ENG	7.228	5.300	N.A.	12.525 GIGA JOULES
AUX. ELECTRIC FUEL	7.228	N.A.	N.A.	7.228 GIGA JOULES
AUX. FOSSIL FUEL	N.A.	8.833	N.A.	8.833 GIGA JOULES
ELECTRICAL SAVINGS	7.067	-0.352	N.A.	5.859 GIGA JOULES
FOSSIL SAVINGS	N.A.	59.285	N.A.	59.285 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.12

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.09

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MONTHLY REPORT: APRIL 1981

SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	155.121 MILLION BTU
	59162 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	63.192 MILLION BTU
	24101 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	59 DEGREES F
AVERAGE BUILDING TEMPERATURE	87 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.24
ECSS OPERATING ENERGY	0.754 MILLION BTU
STORAGE EFFICIENCY	74.44 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.515 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	3.894 MILLION BTU
TOTAL ENERGY CONSUMED	75.494 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	13.631	31.597	N.A.	45.228 MILLION BTU
SOLAR FRACTION	50	97	N.A.	83 PERCENT
SOLAR ENERGY USED	6.780	30.775	N.A.	37.554 MILLION BTU
OPERATING ENERGY	0.081	3.058	N.A.	3.894 MILLION BTU
AUX. THERMAL ENERGY	6.851	0.938	N.A.	7.786 MILLION BTU
AUX. ELECTRIC FUEL	6.851	N.A.	N.A.	6.851 MILLION BTU
AUX. FOSSIL FUEL	N.A.	1.563	N.A.	1.563 MILLION BTU
ELECTRICAL SAVINGS	6.699	-0.334	N.A.	5.610 MILLION BTU
FOSSIL SAVINGS	N.A.	51.291	N.A.	51.291 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.21

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.06

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REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: APRIL 1981
SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM

		CONVENTIONAL UNITS
GENERAL SITE DATA:		
INCIDENT SOLAR ENERGY	155.121	MILLION BTU
	59162	BTU/SQ.FT.
COLLECTED SOLAR ENERGY	63.192	MILLION BTU
	24101	BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	59	PERCENT
COLLECTOR ARRAY EFFICIENCY	0.407	
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	0.495	
AVERAGE AMBIENT TEMPERATURE	59	DEGREES F
AVERAGE BUILDING TEMPERATURE	87	DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.24	
ECSS OPERATING ENERGY	0.754	MILLION BTU
ECSS PERFORMANCE FACTOR	14323	BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	3.894	MILLION BTU
TOTAL ENERGY CONSUMED	75.494	MILLION BTU
SOLAR DELIVERED/BUILDING AREA	954	BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	198	BTU/SQ.FT.

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL	
LOAD	13.631	31.597	N.A.	45.228	MILLION BTU
SOLAR FRACTION	50	97	N.A.	83	PERCENT
SOLAR SAVINGS RATIO	0.492	0.966	N.A.	0.823	
SOLAR ENERGY USED	6.780	30.775	N.A.	37.554	MILLION BTU
OPERATING ENERGY	0.081	3.058	N.A.	3.894	MILLION BTU
AUX. THERMAL ENERGY	6.851	0.938	N.A.	7.786	MILLION BTU
AUX. ELECTRIC FUEL	6.851	N.A.	N.A.	6.851	MILLION BTU
AUX. FOSSIL FUEL	N.A.	1.563	N.A.	1.563	MILLION BTU
ELECTRICAL SAVINGS	6.699	-0.334	N.A.	5.610	MILLION BTU
FOSSIL SAVINGS	N.A.	51.291	N.A.	51.291	MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.06

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

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MONTHLY REPORT: APRIL 1981

SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM

	SI UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	163.653 GIGA JOULES
	671838 KJ/SQ.M.
COLLECTED SOLAR ENERGY	66.668 GIGA JOULES
	273689 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	15 DEGREES C
AVERAGE BUILDING TEMPERATURE	30 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.24
ECSS OPERATING ENERGY	0.796 GIGA JOULES
STORAGE EFFICIENCY	74.44 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	2.926 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	4.108 GIGA JOULES
TOTAL ENERGY CONSUMED	79.646 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	14.381	33.335	N.A.	47.716 GIGA JOULES
SOLAR FRACTION	50	97	N.A.	83 PERCENT
SOLAR ENERGY USED	7.153	32.467	N.A.	39.620 GIGA JOULES
OPERATING ENERGY	0.086	3.226	N.A.	4.108 GIGA JOULES
AUX. THERMAL ENG	7.228	0.989	N.A.	8.214 GIGA JOULES
AUX. ELECTRIC FUEL	7.228	N.A.	N.A.	7.228 GIGA JOULES
AUX. FOSSIL FUEL	N.A.	1.649	N.A.	1.649 GIGA JOULES
ELECTRICAL SAVINGS	7.067	-0.352	N.A.	5.919 GIGA JOULES
FOSSIL SAVINGS	N.A.	54.112	N.A.	54.112 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 1.21

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.06

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REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 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	5.370	54	2.483	N	0.035	0.000	0.462
2	5.801	55	2.392	O	0.035	0.000	0.412
3	5.939	56	2.399	T	0.035	0.000	0.404
4	5.952	60	2.106		0.035	0.000	0.354
5	5.816	61	0.264	A	0.021	0.000	0.045
6	5.882	58	3.086	P	0.034	0.000	0.525
7	5.734	57	2.501	P	0.030	0.000	0.436
8	5.785	55	2.572	L	0.033	0.000	0.445
9	5.794	56	2.282	I	0.033	0.000	0.394
10	5.773	54	2.339	C	0.034	0.000	0.405
11	5.953	53	2.398	A	0.034	0.000	0.403
12	5.851	55	0.148	B	0.021	0.000	0.025
13	5.844	61	2.795	L	0.033	0.000	0.478
14	5.656	59	1.435	E	0.027	0.000	0.254
15	5.469	57	0.854		0.024	0.000	0.156
16	4.969	61	0.717		0.026	0.000	0.144
17	4.467	59	0.047		0.016	0.000	0.010
18	0.483	54	0.417		0.006	0.000	0.863
19	1.468	53	0.108		0.003	0.000	0.074
20	5.074	58	1.138		0.029	0.000	0.224
21	5.455	60	0.496		0.025	0.000	0.091
22	5.650	69	0.412		0.023	0.000	0.073
23	5.533	64	0.491		0.018	0.000	0.089
24	5.362	60	0.460		0.020	0.016	0.086
25	2.636	55	0.218		0.009	0.000	0.083
26	5.703	55	0.229		0.018	0.000	0.040
27	5.713	61	1.422		0.029	0.000	0.249
28	5.603	74	0.397		0.021	0.000	0.071
29	5.458	78	0.475		0.024	0.469	0.087
30	4.929	70	0.476		0.021	0.066	0.097
SUM	155.121	-	37.554	N.A.	0.754	0.551	-
AVG	5.171	59	1.252	N.A.	0.025	0.018	0.242
PFRV	1.0000	1.0000	1.0000	N.A.	1.0000	1.0000	1.0000

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 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	5.370	5.067	2.595	63	0.483	0.512
2	5.801	5.538	2.912	66	0.502	0.526
3	5.939	5.494	2.928	71	0.493	0.533
4	5.952	5.470	2.942	75	0.494	0.538
5	5.816	5.071	2.581	76	0.444	0.509
6	5.882	5.074	2.571	70	0.437	0.507
7	5.734	4.920	2.562	71	0.447	0.521
8	5.785	5.070	2.615	66	0.452	0.516
9	5.794	5.185	2.723	68	0.470	0.525
10	5.773	5.200	2.702	66	0.468	0.520
11	5.953	5.288	2.764	64	0.464	0.523
12	5.851	4.969	2.402	69	0.410	0.483
13	5.844	5.086	2.812	80	0.481	0.553
14	5.656	4.850	2.476	76	0.438	0.510
15	5.469	4.616	2.183	68	0.399	0.473
16	4.969	3.963	1.927	75	0.388	0.486
17	4.467	3.214	1.407	68	0.315	0.438
18	0.483	0.000	0.000	55	0.000	0.000
19	1.468	0.256	0.130	58	0.088	0.506
20	5.074	4.284	2.115	67	0.417	0.494
21	5.455	4.575	2.115	72	0.388	0.462
22	5.650	4.631	2.262	86	0.400	0.489
23	5.533	4.174	1.830	75	0.331	0.438
24	5.362	3.805	1.564	71	0.292	0.411
25	2.636	0.794	0.468	61	0.177	0.589
26	5.703	4.162	1.796	64	0.315	0.431
27	5.713	4.720	2.185	73	0.382	0.463
28	5.603	4.604	2.223	90	0.397	0.483
29	5.458	4.410	2.063	94	0.378	0.468
30	4.929	3.139	1.343	85	0.272	0.428
SUM	155.121	127.631	63.192	-	-	-
AVG	5.171	4.254	2.106	72	0.407	0.495
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 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	1.258	1.537	-0.162	102	0.31
2	1.625	1.428	0.218	102	0.06
3	1.760	1.471	0.276	106	0.03
4	2.068	1.204	0.525	113	0.67
5	2.635	0.456	1.734	137	0.67
6	1.658	2.966	-0.896	137	0.52
7	1.726	1.371	-0.131	129	0.71
8	1.523	1.218	-0.309	124	0.98
9	1.712	1.289	-0.123	120	0.96
10	1.640	1.409	-0.164	117	0.73
11	1.605	1.385	-0.061	114	0.52
12	2.491	0.128	1.704	133	1.04
13	1.903	2.245	-0.657	136	0.39
14	1.847	1.440	0.306	135	0.14
15	1.652	0.572	0.420	143	0.78
16	1.507	0.713	0.157	149	0.73
17	1.236	0.450	0.451	155	0.36
18	0.005	1.001	-0.981	151	0.02
19	0.050	0.084	-0.300	137	0.41
20	1.600	0.493	0.145	133	1.37
21	1.787	0.777	0.640	143	0.40
22	2.015	0.657	0.848	157	0.47
23	1.456	0.824	0.105	165	0.45
24	1.249	0.871	-0.061	165	0.36
25	0.210	0.731	-0.771	156	0.23
26	1.368	0.194	0.584	155	0.56
27	1.603	1.760	-0.379	151	0.21
28	2.136	0.643	0.667	158	0.73
29	1.497	0.674	0.216	167	0.49
30	1.190	0.932	0.098	169	0.13
SUM	46.013	30.924	3.329	-	-
AVG	1.534	1.031	0.111	139	0.52
PFRV	1.0000	1.0000	N.A.	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 1981

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	0.527	15	0.500	13	0.081	0.002	0.446
2	0.509	13	0.476	12	0.067	0.001	0.443
3	0.512	15	0.479	14	0.078	0.002	0.434
4	0.028	36	0.009	26	0.010	0.000	0.018
5	0.053	80	0.009	59	0.042	0.001	0.010
6	0.636	49	0.611	49	0.313	0.004	0.323
7	0.641	42	0.615	42	0.271	0.004	0.371
8	0.640	38	0.617	37	0.242	0.004	0.398
9	0.562	35	0.542	34	0.195	0.004	0.366
10	0.569	30	0.557	29	0.170	0.004	0.399
11	0.043	26	0.032	21	0.011	0.000	0.032
12	0.061	74	0.017	53	0.045	0.001	0.016
13	0.604	47	0.607	47	0.286	0.004	0.318
14	0.605	47	0.583	46	0.284	0.004	0.321
15	0.668	54	0.634	53	0.362	0.004	0.306
16	0.704	58	0.679	58	0.410	0.004	0.294
17	0.058	80	0.032	73	0.047	0.001	0.012
18	0.020	37	0.002	40	0.007	0.000	0.013
19	0.027	63	0.012	66	0.017	0.000	0.010
20	0.643	42	0.644	41	0.273	0.004	0.370
21	0.621	53	0.579	51	0.328	0.004	0.293
22	0.667	62	0.637	61	0.412	0.004	0.255
23	0.672	73	0.650	73	0.491	0.004	0.180
24	0.651	71	0.631	71	0.460	0.004	0.191
25	0.116	73	0.088	72	0.084	0.001	0.031
26	0.031	53	0.009	78	0.017	0.000	0.015
27	0.737	58	0.717	58	0.431	0.004	0.306
28	0.648	61	0.614	60	0.397	0.004	0.252
29	0.692	69	0.688	68	0.475	0.004	0.217
30	0.688	69	0.679	69	0.476	0.004	0.211
SUM	13.631	-	12.948	-	6.780	0.081	6.851
AVG	0.454	50	0.432	49	0.226	0.003	0.228
PFRV	1.0000	1.0000	0.9972	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 1981

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	0.446	N	0.079	N	66	107	1471	0.002
2	0.443	O	0.066	O	67	108	1395	0.001
3	0.434	T	0.076	T	68	102	1696	0.002
4	0.018		0.010		71	120	23	0.000
5	0.010	A	0.041	A	77	118	27	0.001
6	0.323	P	0.309	P	69	121	1415	0.004
7	0.371	P	0.267	P	68	120	1411	0.004
8	0.398	L	0.238	L	69	119	1472	0.004
9	0.366	I	0.191	I	69	121	1274	0.004
10	0.399	C	0.166	C	70	118	1407	0.004
11	0.032	A	0.011	A	70	129	66	0.000
12	0.016	B	0.044	B	77	123	44	0.001
13	0.318	L	0.282	L	69	124	1311	0.004
14	0.321	E	0.280	E	70	124	1299	0.004
15	0.306		0.357		69	124	1380	0.004
16	0.294		0.406		68	123	1477	0.004
17	0.012		0.046		74	130	69	0.001
18	0.013		0.007		81	94	20	0.000
19	0.010		0.017		78	118	37	0.000
20	0.370		0.269		70	119	1563	0.004
21	0.293		0.324		70	121	1351	0.004
22	0.255		0.408		70	126	1358	0.004
23	0.180		0.487		69	130	1292	0.004
24	0.191		0.456		69	131	1218	0.004
25	0.031		0.083		70	129	180	0.001
26	0.015		0.016		74	118	25	0.000
27	0.306		0.427		69	119	1736	0.004
28	0.252		0.393		70	128	1258	0.004
29	0.217		0.471		70	128	1417	0.004
30	0.211		0.472		71	126	1476	0.004
SUM	6.851	N.A.	6.699	N.A.	-	-	30167	0.081
AVG	0.228	N.A.	0.223	N.A.	69	121	1006	0.003
PFRV	1.0000	N.A.	1.0000	N.A.	0.9972	0.9972	0.9972	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 1981

SPACE HEATING SUBSYSTEM I

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	CONTROLLED DELIVERED ENERGY MILLION BTU	TOTAL SOLAR ENERGY USED MILLION BTU (Q400)	TOTAL AUXILIARY THERMAL USED MILLION BTU (Q401)	SOLAR FRACTION OF LOAD PCT (N400)	ELECT ENERGY SAVINGS MILLION BTU (Q415)	FOSSIL ENERGY SAVINGS MILLION BTU (Q417)	BLDG TEMP DEG F (N406)	AMB TEMP DEG F (N113)
1	2.589	2.589	2.401	0.188	93	-0.022	4.002	72	54
2	2.520	2.520	2.325	0.195	92	-0.021	3.875	71	55
3	2.486	2.486	2.321	0.165	93	-0.020	3.869	71	56
4	2.216	2.216	2.096	0.121	95	-0.017	3.493	71	60
5	0.225	0.225	0.221	0.004	98	-0.001	0.369	75	61
6	2.778	2.778	2.773	0.006	100	-0.017	4.621	73	58
7	2.142	2.142	2.230	0.027	98	-0.014	3.717	72	57
8	2.343	2.343	2.330	0.013	99	-0.018	3.883	71	55
9	2.101	2.101	2.087	0.014	99	-0.018	3.478	71	56
10	2.218	2.218	2.169	0.049	98	-0.019	3.616	71	54
11	2.488	2.488	2.387	0.101	96	-0.020	3.978	70	53
12	0.105	0.105	0.103	0.002	98	-0.001	0.172	70	55
13	2.556	2.556	2.509	0.047	98	-0.017	4.181	73	61
14	1.158	1.158	1.151	0.007	99	-0.011	1.919	83	59
15	0.492	0.492	0.492	0.000	100	-0.009	0.821	105	57
16	0.307	0.307	0.307	0.000	100	-0.013	0.511	106	61
17	0.000	0.000	0.000	0.000	0	-0.004	0.000	108	59
18	0.410	0.410	0.410	0.000	100	-0.006	0.683	108	54
19	0.091	0.091	0.091	0.000	100	-0.001	0.152	67	53
20	0.865	0.865	0.865	0.000	100	-0.013	1.442	112	58
21	0.169	0.169	0.169	0.000	100	-0.011	0.281	106	60
22	0.000	0.000	0.000	0.000	0	-0.006	0.000	93	69
23	0.000	0.000	0.000	0.000	0	-0.007	0.000	99	64
24	0.000	0.000	0.000	0.000	0	-0.009	0.000	104	60
25	0.133	0.133	0.133	0.000	100	-0.005	0.222	108	55
26	0.212	0.212	0.212	0.000	100	-0.003	0.354	95	55
27	0.991	0.991	0.991	0.000	100	-0.016	1.652	116	61
28	0.000	0.000	0.000	0.000	0	-0.004	0.000	89	74
29	0.000	0.000	0.000	0.000	0	-0.003	0.000	87	78
30	0.000	0.000	0.000	0.000	0	-0.008	0.000	88	70
SUM	31.597	31.597	30.775	0.938	-	-0.334	51.291	-	-
AVG	1.053	1.053	1.026	0.031	97	-0.011	1.710	87	59
PFRV	0.9986	0.9986	1.0000	0.9986	0.9986	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 1981

SPACE HEATING SUBSYSTEM II

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	MEASURED SOLAR ENERGY USED MILLION BTU	SOLAR ENERGY LOSSES TO LOAD MILLION BTU	TOTAL OPERATING ENERGY MILLION BTU (Q403)	SOLAR SPECIFIC OPERATING ENERGY MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q410)	HEATING DEGREE DAYS
1	2.589	2.401	0.000	0.277	0.022	N	0.313	8
2	2.520	2.325	0.000	0.268	0.021	O	0.324	8
3	2.486	2.321	0.000	0.270	0.020	T	0.275	7
4	2.216	2.096	0.000	0.256	0.017		0.201	3
5	0.225	0.221	0.000	0.014	0.001	A	0.007	2
6	2.778	2.773	0.000	0.289	0.017	P	0.009	4
7	2.142	2.230	0.000	0.217	0.014	P	0.045	4
8	2.343	2.330	0.000	0.220	0.018	L	0.022	7
9	2.101	2.087	0.000	0.223	0.018	I	0.024	8
10	2.218	2.169	0.000	0.230	0.019	C	0.081	9
11	2.488	2.387	0.000	0.244	0.020	A	0.168	11
12	0.105	0.103	0.000	0.014	0.001	B	0.004	8
13	2.556	2.509	0.000	0.267	0.017	L	0.078	1
14	1.158	1.151	0.000	0.152	0.011	E	0.012	3
15	0.492	0.492	0.000	0.009	0.009		0.000	6
16	0.307	0.307	0.000	0.013	0.013		0.000	1
17	0.000	0.000	0.000	0.004	0.004		0.000	2
18	0.410	0.410	0.000	0.006	0.006		0.000	11
19	0.091	0.091	0.000	0.001	0.001		0.000	8
20	0.865	0.865	0.000	0.013	0.013		0.000	5
21	0.169	0.169	0.000	0.011	0.011		0.000	4
22	0.000	0.000	0.000	0.006	0.006		0.000	0
23	0.000	0.000	0.000	0.007	0.007		0.000	0
24	0.000	0.000	0.000	0.009	0.009		0.000	2
25	0.133	0.133	0.000	0.005	0.005		0.000	6
26	0.212	0.212	0.000	0.003	0.003		0.000	8
27	0.991	0.991	0.000	0.016	0.016		0.000	2
28	0.000	0.000	0.000	0.004	0.004		0.000	0
29	0.000	0.000	0.000	0.003	0.003		0.000	0
30	0.000	0.000	0.000	0.008	0.008		0.000	0
SUM	31.597	30.775	0.000	3.058	0.334	N.A.	1.563	139
AVG	1.053	1.026	0.000	0.102	0.011	N.A.	0.052	5
PFRV	0.9986	1.0000	1.0000	1.0000	1.0000	N.A.	0.9986	N.A.

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM APRIL 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	2048	N	54	63	84	282	3
2	2212	O	55	66	80	289	3
3	2265	T	56	71	83	0	1
4	2270		60	75	77	0	1
5	2218	A	61	76	81	0	1
6	2243	P	58	70	86	0	1
7	2187	P	57	71	85	0	2
8	2206	L	55	66	85	274	3
9	2210	I	56	68	86	0	1
10	2202	C	54	66	82	278	2
11	2270	A	53	64	82	280	2
12	2232	B	55	69	84	0	1
13	2229	L	61	80	80	0	1
14	2157	E	59	76	90	0	1
15	2086		57	68	94	0	1
16	1895		61	75	89	0	1
17	1704		59	68	98	0	1
18	184		54	55	103	221	2
19	560		53	58	94	279	2
20	1935		58	67	88	0	1
21	2080		60	72	92	0	1
22	2155		69	86	79	0	1
23	2110		64	75	95	0	1
24	2045		60	71	94	0	1
25	1005		55	61	92	296	2
26	2175		55	64	85	289	3
27	2179		61	73	81	0	2
28	2137		74	90	70	0	1
29	2082		78	94	69	0	1
30	1880		70	85	89	0	1
SUM	59162	N.A.	-	-	-	-	-
AVG	1972	N.A.	59	72	86	0	2
PFRV	1.0000	N.A.	1.0000	1.0000	1.0000	0.9917	1.0000

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MONTHLY REPORT: APRIL 1981

SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	45.437 MILLION BTU
	27127 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	2.942 MILLION BTU
	1756 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	63 DEGREES F
AVERAGE BUILDING TEMPERATURE	79 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.06
ECSS OPERATING ENERGY	0.057 MILLION BTU
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	0.764 MILLION BTU
TOTAL ENERGY CONSUMED	10.517 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	7.028	N.A.	7.028 MILLION BTU
SOLAR FRACTION	N.A.	42	N.A.	42 PERCENT
SOLAR ENERGY USED	N.A.	2.942	N.A.	2.942 MILLION BTU
OPERATING ENERGY	N.A.	0.707	N.A.	0.764 MILLION BTU
AUX. THERMAL ENERGY	N.A.	4.086	N.A.	4.086 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	6.810	N.A.	6.810 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.057 MILLION BTU
FOSSIL SAVINGS	N.A.	4.903	N.A.	4.903 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.75

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.10

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
SOLAR/0004-80/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: APRIL 1981
SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	45.437 MILLION BTU
	27127 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	2.942 MILLION BTU
	1756 BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	100 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.065
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	1.129
AVERAGE AMBIENT TEMPERATURE	63 DEGREES F
AVERAGE BUILDING TEMPERATURE	79 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.06
ECSS OPERATING ENERGY	0.057 MILLION BTU
ECSS PERFORMANCE FACTOR	1756 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	0.764 MILLION BTU
TOTAL ENERGY CONSUMED	10.517 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	142 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	197 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	7.028	N.A.	7.028 MILLION BTU
SOLAR FRACTION	N.A.	42	N.A.	42 PERCENT
SOLAR SAVINGS RATIO	N.A.	0.417	N.A.	0.417
SOLAR ENERGY USED	N.A.	2.942	N.A.	2.942 MILLION BTU
OPERATING ENERGY	N.A.	0.707	N.A.	0.764 MILLION BTU
AUX. THERMAL ENERGY	N.A.	4.086	N.A.	4.086 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	6.810	N.A.	6.810 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.057 MILLION BTU
FOSSIL SAVINGS	N.A.	4.903	N.A.	4.903 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.10

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
SOLAR/0004-80/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: APRIL 1981
SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	47.936	GIGA JOULES
	308049	KJ/SQ.M.
COLLECTED SOLAR ENERGY	3.104	GIGA JOULES
	19946	KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	17	DEGREES C
AVERAGE BUILDING TEMPERATURE	26	DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.06	
ECSS OPERATING ENERGY	0.060	GIGA JOULES
STORAGE EFFICIENCY	N.A.	PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A.	W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	0.806	GIGA JOULES
TOTAL ENERGY CONSUMED	11.096	GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL	
LOAD	N.A.	7.414	N.A.	7.414	GIGA JOULES
SOLAR FRACTION	N.A.	42	N.A.	42	PERCENT
SOLAR ENERGY USED	N.A.	3.104	N.A.	3.104	GIGA JOULES
OPERATING ENERGY	N.A.	0.746	N.A.	0.806	GIGA JOULES
AUX. THERMAL ENG	N.A.	4.311	N.A.	4.311	GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A.	GIGA JOULES
AUX. FOSSIL FUEL	N.A.	7.184	N.A.	7.184	GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.060	GIGA JOULES
FOSSIL SAVINGS	N.A.	5.173	N.A.	5.173	GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.75

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.10

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
SOLAR/0004-80/18

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM APRIL 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	1.851	57	0.446	N	0.008	N	0.241
2	2.250	58	0.200	O	0.003	O	0.089
3	1.978	59	0.296	T	0.005	T	0.150
4	1.874	62	0.062		0.001		0.033
5	1.838	63	0.000	A	0.000	A	0.000
6	1.873	61	0.036	P	0.002	P	0.019
7	1.846	60	0.004	P	0.001	P	0.002
8	1.785	57	0.430	L	0.007	L	0.241
9	1.735	59	0.290	I	0.006	I	0.167
10	1.754	57	0.354	C	0.006	C	0.202
11	1.764	57	0.000	A	0.000	A	0.000
12	1.711	58	0.000	B	0.000	B	0.000
13	1.687	63	0.122	L	0.003	L	0.073
14	1.641	63	0.163	E	0.004	E	0.099
15	1.645	61	0.232		0.005		0.141
16	1.539	64	0.000		0.000		0.000
17	1.424	63	0.000		0.000		0.000
18	0.131	57	0.000		0.000		0.000
19	0.496	55	0.000		0.000		0.000
20	1.462	62	0.209		0.004		0.143
21	1.467	63	0.000		0.000		0.000
22	1.423	72	0.000		0.000		0.000
23	1.410	68	0.000		0.000		0.000
24	1.421	64	0.000		0.000		0.000
25	0.819	58	0.097		0.002		0.118
26	1.447	59	0.000		0.000		0.000
27	1.359	65	0.000		0.000		0.000
28	1.283	76	0.000		0.000		0.000
29	1.310	80	0.000		0.000		0.000
30	1.215	75	0.000		0.000		0.000
SUM	45.437	-	2.942	N.A.	0.057	N.A.	-
AVG	1.515	63	0.098	N.A.	0.002	N.A.	0.065
PFRV	1.0000	1.0000	1.0000	N.A.	1.0000	N.A.	1.0000

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM APRIL 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	1.851	0.413	0.446	65	0.241	1.079
2	2.250	0.207	0.200	68	0.089	0.963
3	1.978	0.248	0.296	69	0.150	1.192
4	1.874	0.045	0.062	73	0.033	1.366
5	1.838	0.000	0.000	75	0.000	0.000
6	1.873	0.069	0.036	68	0.019	0.523
7	1.846	0.022	0.004	71	0.002	0.178
8	1.785	0.344	0.430	66	0.241	1.250
9	1.735	0.273	0.290	70	0.167	1.065
10	1.754	0.302	0.354	64	0.202	1.172
11	1.764	0.000	0.000	66	0.000	0.000
12	1.711	0.000	0.000	68	0.000	0.000
13	1.687	0.129	0.122	76	0.073	0.950
14	1.641	0.140	0.163	75	0.099	1.163
15	1.645	0.205	0.232	68	0.141	1.136
16	1.539	0.000	0.000	75	0.000	0.000
17	1.424	0.000	0.000	69	0.000	0.000
18	0.131	0.000	0.000	57	0.000	0.000
19	0.496	0.000	0.000	58	0.000	0.000
20	1.462	0.146	0.209	68	0.143	1.433
21	1.467	0.000	0.000	74	0.000	0.000
22	1.423	0.000	0.000	85	0.000	0.000
23	1.410	0.000	0.000	79	0.000	0.000
24	1.421	0.000	0.000	73	0.000	0.000
25	0.819	0.063	0.097	63	0.118	1.546
26	1.447	0.000	0.000	68	0.000	0.000
27	1.359	0.000	0.000	74	0.000	0.000
28	1.283	0.000	0.000	88	0.000	0.000
29	1.310	0.000	0.000	92	0.000	0.000
30	1.215	0.000	0.000	85	0.000	0.000
SUM	45.437	2.607	2.942	-	-	-
AVG	1.515	0.087	0.098	72	0.065	1.129
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM APRIL 1981

SPACE HEATING SUBSYSTEM I

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	CONTROLLED DELIVERED ENERGY MILLION BTU	TOTAL SOLAR ENERGY USED MILLION BTU (Q400)	TOTAL AUXILIARY THERMAL USED MILLION BTU (Q401)	SOLAR FRACTION OF LOAD PCT (N400)	ELECT ENERGY SAVINGS MILLION BTU (Q415)	FOSSIL ENERGY SAVINGS MILLION BTU (Q417)	BLDG TEMP DEG F (N406)	AMB TEMP DEG F (N113)
1	0.933	0.933	0.446	0.487	48	N	0.743	77	57
2	0.688	0.688	0.200	0.489	29	O	0.333	77	58
3	0.764	0.764	0.296	0.468	39	T	0.493	78	59
4	0.671	0.671	0.062	0.609	9		0.103	79	62
5	0.006	0.006	0.000	0.006	0	A	0.000	78	63
6	0.049	0.049	0.036	0.013	74	P	0.060	78	61
7	0.016	0.016	0.004	0.012	25	P	0.007	78	60
8	0.571	0.571	0.430	0.141	75	L	0.716	77	57
9	0.568	0.568	0.290	0.278	51	I	0.484	78	59
10	0.781	0.781	0.354	0.427	45	C	0.590	78	57
11	0.566	0.566	0.000	0.566	0	A	0.000	78	57
12	0.008	0.008	0.000	0.008	0	B	0.000	76	58
13	0.566	0.566	0.122	0.444	22	L	0.204	80	63
14	0.170	0.170	0.163	0.007	96	E	0.272	79	63
15	0.240	0.240	0.232	0.007	97		0.387	78	61
16	0.011	0.011	0.000	0.011	0		0.000	79	64
17	0.002	0.002	0.000	0.002	0		0.000	78	63
18	0.002	0.002	0.000	0.002	0		0.000	76	57
19	0.022	0.022	0.000	0.022	0		0.000	75	55
20	0.234	0.234	0.209	0.025	89		0.349	79	62
21	0.003	0.003	0.000	0.003	0		0.000	78	63
22	0.007	0.007	0.000	0.007	0		0.000	81	72
23	0.010	0.010	0.000	0.010	0		0.000	81	68
24	0.006	0.006	0.000	0.006	0		0.000	79	64
25	0.101	0.101	0.097	0.004	96		0.162	77	58
26	0.008	0.008	0.000	0.008	0		0.000	75	59
27	0.006	0.006	0.000	0.006	0		0.000	80	65
28	0.003	0.003	0.000	0.003	0		0.000	83	76
29	0.008	0.008	0.000	0.008	0		0.000	86	80
30	0.010	0.010	0.000	0.010	0		0.000	85	75
SUM	7.028	7.028	2.942	4.086	-	N.A.	4.903	-	-
AVG	0.234	0.234	0.098	0.136	42	N.A.	0.163	79	63
PFRV	0.9972	0.9972	1.0000	0.9972	0.9972	N.A.	1.0000	1.0000	1.0000

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM APRIL 1981

SPACE HEATING SUBSYSTEM II

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	MEASURED SOLAR ENERGY USED MILLION BTU	SOLAR ENERGY LOSSES TO LOAD MILLION BTU	TOTAL OPERATING ENERGY MILLION BTU (Q403)	SOLAR SPECIFIC OPERATING ENERGY MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q410)	HEATING DEGREE DAYS
1	0.933	0.446	0.000	0.046	0.000	N	0.811	5
2	0.688	0.200	0.000	0.052	0.000	O	0.814	4
3	0.764	0.296	0.000	0.048	0.000	T	0.779	6
4	0.671	0.062	0.000	0.043	0.000		1.014	1
5	0.006	0.000	0.000	0.000	0.000	A	0.010	0
6	0.049	0.036	0.000	0.030	0.000	P	0.021	2
7	0.016	0.004	0.000	0.029	0.000	P	0.019	4
8	0.571	0.430	0.000	0.045	0.000	L	0.235	7
9	0.568	0.290	0.000	0.046	0.000	I	0.463	5
10	0.781	0.354	0.000	0.049	0.000	C	0.712	6
11	0.566	0.000	0.000	0.051	0.000	A	0.943	8
12	0.008	0.000	0.000	0.000	0.000	B	0.013	5
13	0.566	0.122	0.000	0.052	0.000	L	0.740	0
14	0.170	0.163	0.000	0.024	0.000	E	0.011	0
15	0.240	0.232	0.000	0.024	0.000		0.012	3
16	0.011	0.000	0.000	0.021	0.000		0.018	0
17	0.002	0.000	0.000	0.000	0.000		0.003	1
18	0.002	0.000	0.000	0.013	0.000		0.003	9
19	0.022	0.000	0.000	0.007	0.000		0.036	9
20	0.234	0.209	0.000	0.052	0.000		0.041	1
21	0.003	0.000	0.000	0.013	0.000		0.005	1
22	0.007	0.000	0.000	0.000	0.000		0.012	0
23	0.010	0.000	0.000	0.000	0.000		0.016	0
24	0.006	0.000	0.000	0.000	0.000		0.010	0
25	0.101	0.097	0.000	0.009	0.000		0.007	6
26	0.008	0.000	0.000	0.009	0.000		0.013	5
27	0.006	0.000	0.000	0.043	0.000		0.010	0
28	0.003	0.000	0.000	0.000	0.000		0.005	0
29	0.008	0.000	0.000	0.000	0.000		0.014	0
30	0.010	0.000	0.000	0.000	0.000		0.017	0
SUM	7.028	2.942	0.000	0.707	0.000	N.A.	6.810	88
AVG	0.234	0.098	0.000	0.024	0.000	N.A.	0.227	3
PFRV	0.9972	1.0000	1.0000	1.0000	1.0000	N.A.	0.9972	N.A.

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<40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM APRIL 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	1105	N	57	65	84	282	3
2	1344	O	58	68	80	289	3
3	1181	T	59	69	83	0	1
4	1119		62	73	77	0	1
5	1097	A	63	75	81	0	1
6	1118	P	61	68	86	0	1
7	1102	P	60	71	85	0	2
8	1066	L	57	66	85	274	3
9	1036	I	59	70	86	0	1
10	1047	C	57	64	82	278	2
11	1053	A	57	66	82	280	2
12	1021	B	58	68	84	0	1
13	1007	L	63	76	80	0	1
14	980	E	63	75	90	0	1
15	982		61	68	94	0	1
16	919		64	75	89	0	1
17	850		63	69	98	0	1
18	78		57	57	103	221	2
19	296		55	58	94	279	2
20	873		62	68	88	0	1
21	876		63	74	92	0	1
22	849		72	85	79	0	1
23	842		68	79	95	0	1
24	848		64	73	94	0	1
25	489		58	63	92	296	2
26	864		59	68	85	289	3
27	811		65	74	81	0	2
28	766		76	88	70	0	1
29	782		80	92	69	0	1
30	725		75	85	89	0	1
SUM	27127	N.A.	-	-	-	-	-
AVG	904	N.A.	63	72	86	0	2
PFRV	1.0000	N.A.	1.0000	1.0000	1.0000	0.9917	1.0000

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

*U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2576