SOLAR/2076-82/14
(DE82021353)
Distribution Category UC-59

OAKMEAD INDUSTRIES

SANTA CLARA, CALIFORNIA

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

JUNE 1981 THROUGH APRIL 1982

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Department of Energy Contract Number DE-AC01-79CS30027
Contract Management by:
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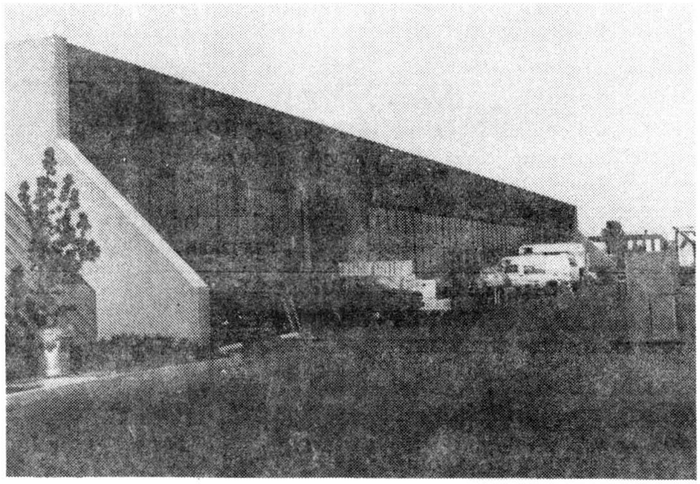
FOREWORD

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.

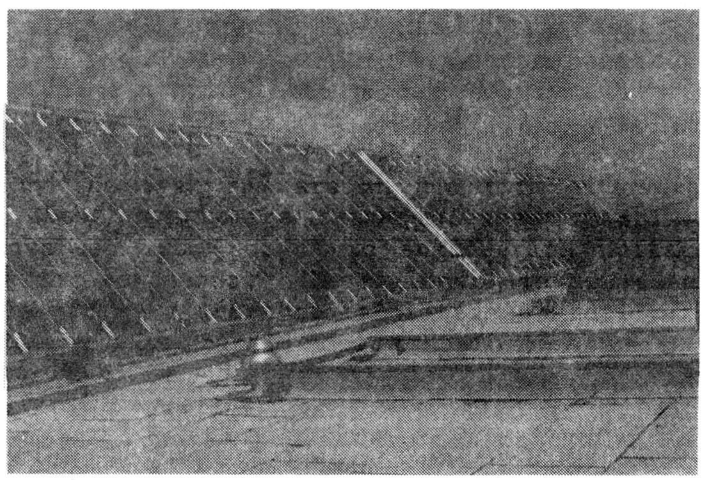
The National Solar Data Network consists of instrumented solar energy systems in buildings selected from among the 5,000 installations built (since early 1977) as part of the National Solar Heating and Cooling Demonstration Program. The overall purpose of this program is to assist in the development 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 site is a commercial office/manufacturing building located in Santa Clara, California. The solar energy system is designed to supply the following:

Annual Design Factors

	% Solar
Space Heating	85
Hot Water	90

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 air collectors
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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Solar Fraction[1]	49%
Solar Savings Ratio[2]	0.46
Conventional Fuel Savings[3]	305,310 cubic feet of natural gas 12,429 kwh of electrical energy
System Performance Factor[4]	0.59
Solar System COP[5]	12.60

Seasonal Energy Requirements
June 1981 through April 1982
(Million BTU)

	Total Load	Solar Contribution	% Solar
Heating	371.55	187.04	50
Hot Water	131.91	62.23	47

Environmental Data

	Measured Average	Long-Term Average
Outdoor temperature	63°F	60°F
Heating degree-days (Total)	1,535	2,293
Cooling degree-days (Total)	743	424
Daily incident solar energy	1,490 BTU/ft^2	1,646 BTU/ft^2

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

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

3. Conventional Fuel Savings = Savings in BTU x 979.4 x 10^{-6} cubic feet/BTU
   Savings in BTU x 292.8 x 10^{-6} kwh/BTU

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

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

1.1 SUMMARY AND CONCLUSIONS

The Oakmead Industries solar energy system supplied 49% of the space heating and Domestic Hot Water (DHW) loads during the June 1981 through April 1982 reporting period. The solar system provided 50% of the space heating load and 47% of the DHW load as compared to the design expectations of 85% for the space heating subsystem and 90% for the DHW subsystem. Solar system operation accounted for a fossil fuel energy savings of 3,053 therms (100 cubic feet) of natural gas and 12,429 kwh of electrical energy. These energy savings are equivalent to $2,023.66 based on actual utility rates. The system thermal performance is summarized in Table 1.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(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	
JUN	56.25	14.84	8.83	6.01	0.00	6.01	1.44	0.00	7.39	60
JUL	54.46	14.53	8.77	5.76	0.00	5.76	3.07	0.00	7.12	60
AUG	52.99	13.68	8.91	4.77	0.00	4.77	5.42	0.00	7.53	65
SEP	49.52	21.38	13.54	7.84	0.00	7.84	4.57	0.00	12.18	63
OCT	45.98	33.02	8.70	24.32	32.00	5.12	10.83	0.00	7.39	26
NOV	33.75	51.56	24.89	26.67	33.57	6.53	11.33	36.71	0.83	48
DEC	27.67	48.58	19.72	28.86	38.58	5.71	10.26	30.27	-0.40	40
JAN	40.52	99.70	31.32	68.38	99.99	8.39	12.50	49.58	-0.73	31
FEB	46.34	71.81	40.59	31.22	40.74	6.78	11.01	63.22	0.75	56
MAR	41.67	65.96	33.93	32.03	42.05	6.80	11.07	53.48	-0.52	51
APR	61.40	68.40	50.07	18.33	20.60	5.97	10.56	78.47	0.91	73
TOTAL	510.55	503.46	249.27	254.19	307.53	69.68	92.06	311.73	42.45	-
AVERAGE	46.41	45.77	22.66	23.11	27.96	6.33	8.37	28.34	3.86	49(1)

(1)Denotes Weighted Average.

The solar system operated well and encountered very little maintenance during the reporting period. Good solar collector array efficiency and low operating energy accounted for the good energy savings. The oversized storage tank provided low collector inlet temperatures which enhanced the collector array efficiency. The solar portion of the DHW subsystem was underdesigned for the actual loads measured. If pump P4 were larger or if the cold water supply had a heat exchanger immersed in the storage tank, the solar contribution could have been greater, with higher effective savings and less equipment costs.

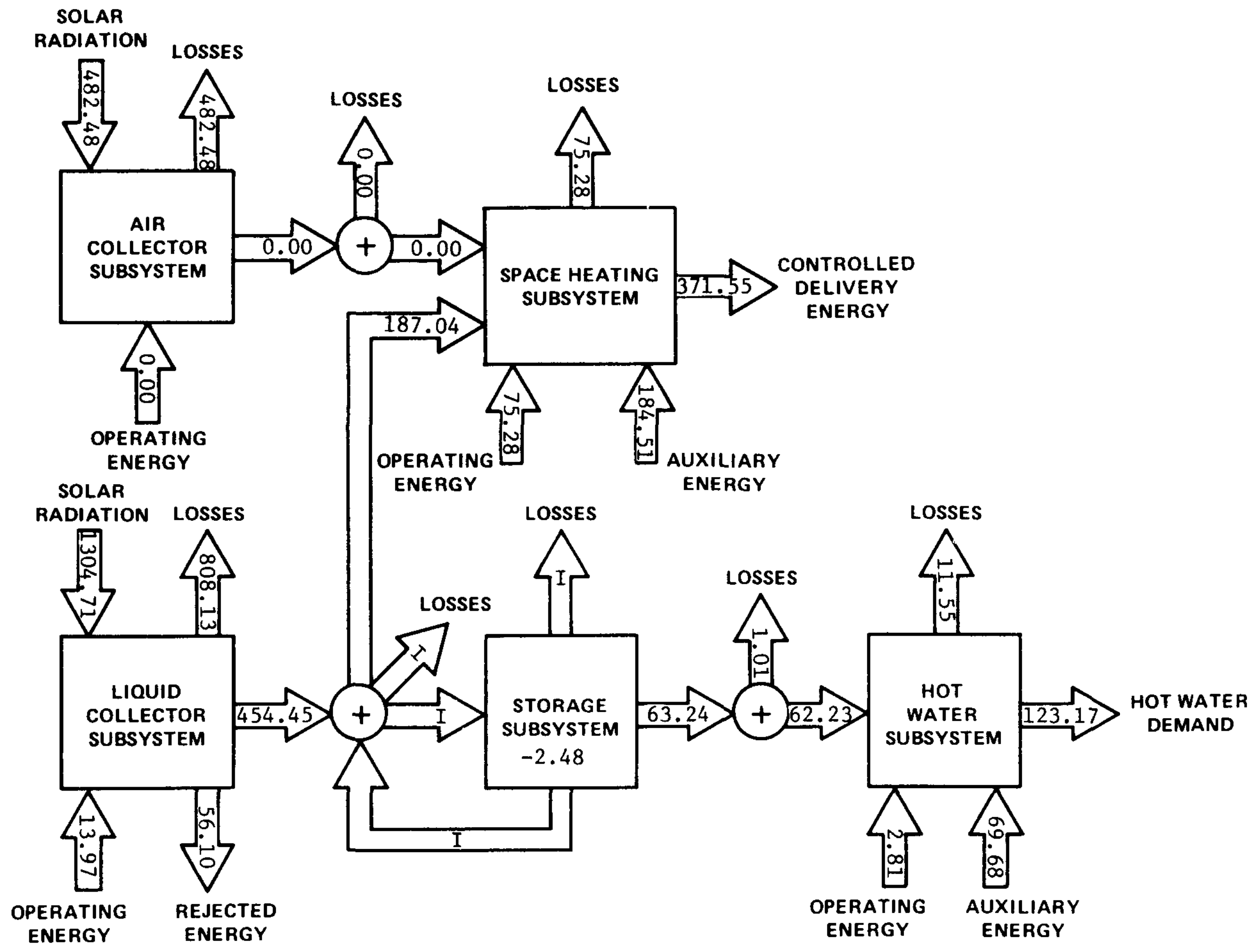
Control, HVAC (Heating, Ventilating, and Air Conditioning), and design deficiencies lowered the system performance below expectations. The major deficiencies are summarized below and explained in more detail in the text.

- The space heating time clock schedule operated the HVAC equipment beyond the normal occupied periods and caused larger quantities of auxiliary energy to be used.
- The solar storage tank is oversized.
- The weather conditions were well below the expected insolation levels.
- The collector pump operated all day and night at times due to improper control operation.
- The heat rejector was improperly activating at a lower set point temperature.
- The storage to preheat tank pump, P4, had a control deficiency which operated the pump all day long after November.
- Solar space heating was not utilized until November 6, while there was space heating beginning on October 12.
- The south zone fan was operating at all times from July 22 through November 6 to recirculate interior air. This resulted in larger quantities of operating energy being used.
- The collector connections leaked during part of the summer when high collector temperatures were common.

It should be noted that the instrumentation was installed to evaluate the active performance of the air system on the south wall. However, the south wall also operates in the passive mode, but the sensors can only measure energy transfers in the air ducts. No passive analysis was included in this performance evaluation. Also, the south zone space heating unit, which includes the south wall air collectors, was deactivated by the grantee during the heating season. The entire space heating load was supplied by the north zone space heating unit.

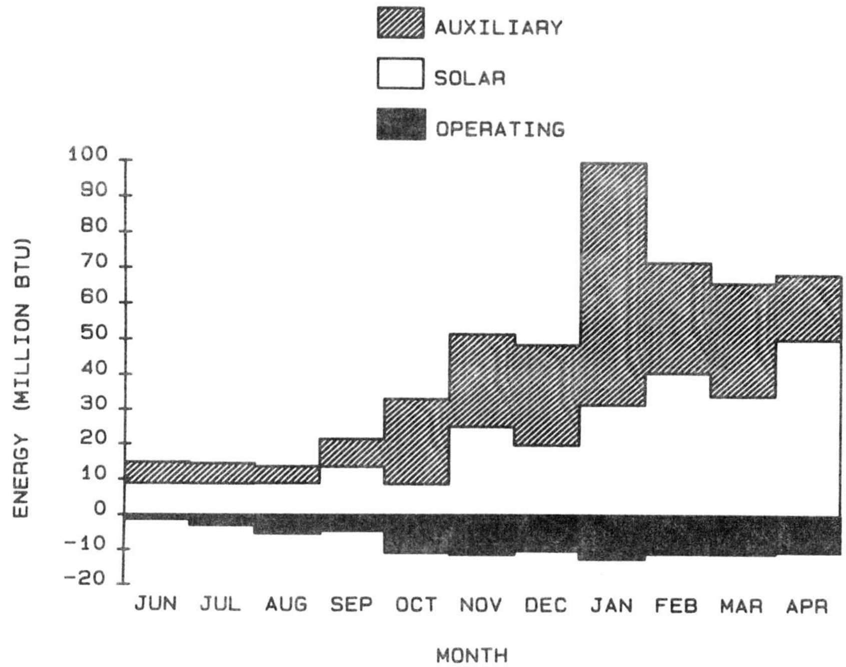
The flow of solar energy through the Oakmead Industries system is presented in Figure 1. The Energy Flow Diagram represents the amount of energy collected, transported, lost, and consumed at each point in the system. Figure 1 shows that the air collector subsystem was deactivated. Storage performance evaluation was invalidated, due to a problem with flow meter W201.

A graphical representation of the system thermal performance is depicted in Figure 2. This figure shows solar, auxiliary, and operating energies used for the HVAC system. The solar contribution was 49% of the total thermal energy expenditure. The load during April 1982 seems relatively high. This is due to improper heating system operation which resulted in some localized overheating.



I Denotes invalid data.

Figure 1. Energy Flow Diagram for Oakmead Industries
June 1981 through April 1982
(Figures in million BTU)



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

Figure 2. System Thermal Performance
Oakmead Industries
June 1981 through April 1982

The solar energy Coefficient of Performance (COP) is shown 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. The overall solar energy system COP was 12.60. Note that as solar energy utilization increases, there is an increase in solar COP also. The collector subsystem operated efficiently at a COP of 36.55. Since the collector pump operated many times during the night, the solar COP was lower than expected. The DHW subsystem COP was very high during the summer months, but lower during the space heating season. This performance was due to the fact that the heating subsystem has priority use of solar energy and also that pump P4 was operating continuously from December 1981 through April 1982. These factors resulted in the COP of 22.15. The space heating subsystem had the highest COP of 62.35. This value was reduced somewhat because pump P2 was operating continuously during June 1981 and July 1981 with no contribution to the load.

The collector array at Oakmead Industries performed very well during the reporting period. The collector array efficiency was 39% while the collector array operating efficiency was 46%. The collector performance was enhanced due to the lower collector inlet temperatures provided by the oversized storage tank. However, the collector array required the rejection of 56.10 million BTU for protection from high temperatures. The collector array performance is shown in Table 3.

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	DOMESTIC HOT WATER SUBSYSTEM	SPACE HEATING SUBSYSTEM
JUN	6.13	65.41	98.11	0.00
JUL	5.32	49.96	62.64	0.00
AUG	6.46	42.73	63.64	0.00
SEP	9.96	41.97	75.22	0.00
OCT	6.64	39.98	54.38	0.00
NOV	12.26	22.96	9.86	81.59
DEC	10.06	20.35	4.22	78.96
JAN	13.62	26.31	4.13	78.29
FEB	21.25	41.01	7.82	86.20
MAR	14.38	25.41	4.97	91.69
APR	24.07	46.87	8.54	112.10
WEIGHTED AVERAGE	12.60	36.55	22.15	62.35

Table 3. LIQUID COLLECTOR SUBSYSTEM PERFORMANCE

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(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	DAYTIME AMBIENT TEMPERATURE (°F)
JUN	152.96	56.25	37	122.95	46	0.00	0.86	8.83	82
JUL	151.78	54.46	36	117.34	46	0.00	1.09	8.77	79
AUG	151.53	52.99	35	116.73	45	21.48	1.24	8.91	78
SEP	138.39	49.52	36	107.55	46	15.73	1.18	13.54	79
OCT	130.19	45.98	35	97.10	47	16.35	1.15	8.70	74
NOV	81.57	33.75	41	73.79	46	2.47	1.47	24.89	67
DEC	64.89	27.67	43	61.76	45	0.00	1.36	19.72	62
JAN	95.12	40.52	43	91.75	44	0.00	1.54	31.32	57
FEB	101.94	46.34	46	90.88	51	0.07	1.13	40.59	66
MAR	102.16	41.67	41	98.21	42	0.00	1.64	33.93	61
APR	134.18	61.40	46	125.88	49	0.00	1.31	50.07	68
TOTAL	1,304.71	510.55	-	1,103.94	-	56.10	13.97	249.27	-
AVERAGE	118.61	46.41	39(1)	100.36	46(1)	5.10	1.27	22.66	70

(1)Denotes Weighted Average.

The large losses (81% of the losses) between collected solar energy and solar energy used occurred during DHW preheating from June 1981 through October 1981. Another 11% of the losses was due to collector loop losses, and the remaining losses are attributed to storage and temperature control loop losses.

Some minor problems were experienced with the collector subsystem. The collector control activated the collector pump occasionally during the night. The problem occurred during low insolation levels that were apparently in the dead-band zone of the controls. The heat rejector unit had a low set point of approximately 174°F, which caused unnecessary energy rejection. Also, the collector manifold connections leaked during the summer months, when high temperatures were common.

The storage subsystem performance is depicted in Table 4. Most performance factors have been invalidated due to inaccurate measurements on flow meter W201 caused by the modulating valve, AV2. The storage tank did maintain an average storage temperature of 119°F with a high temperature of 157°F in August and a low temperature of 83°F in January. The storage tank may be slightly oversized for the system since the ratio of the storage capacity to collector area is 2.5 and a typical "rule of thumb" value is 2.00. However, this larger volume permitted lower collector inlet temperatures which increased the wintertime collector performance.

Table 4. STORAGE PERFORMANCE

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMPERATURE (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/ft^2-hr°F)	LOSS FROM STORAGE
JUN	38.60	30.64	0.38	80	151	0.29	7.58
JUL	35.11	31.28	0.74	91	149	0.12	3.09
AUG	25.93	24.30	-0.16	93	157	0.05	1.79
SEP	29.54	28.80	0.08	98	152	0.06	0.66
OCT	I	I	0.53	I	152	I	I
NOV	I	I	-3.72	I	97	I	I
DEC	I	I	-0.64	I	86	I	I
JAN	I	I	1.44	I	83	I	I
FEB	I	I	-1.67	I	94	I	I
MAR	I	I	-0.78	I	86	I	I
APR	I	I	1.32	I	97	I	I
TOTAL	I	I	-2.48	I	-	I	I
AVERAGE	I	I	-0.23	I	119	I	I

I Denotes invalid data.

The DHW subsystem performance is displayed in Table 5. The DHW load at Oakmead Industries was 131.91 million BTU. The solar energy used was 62.23 million BTU and the auxiliary energy used was 69.68 million BTU, representing a solar contribution of 47%. The DHW demand was 123.17 million BTU, which shows very little standby losses. A total of 326,469 gallons of hot water was used at a average supply temperature of 69°F and a hot water temperature of 116°F.

Table 5. DOMESTIC HOT WATER SUBSYSTEM

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD	SOLAR FRACTION OF LOAD (%)	HOT WATER DEMAND	SOLAR ENERGY USED	AUX THERMAL USED	AUX ELECT FUEL	OPERATING ENERGY	SUP WATER TEMP (°F)	HOT WATER TEMP (°F)	TEMPERED HOT WATER CONSUMPTION (GALLONS)	UNTEMPERED HOT WATER CONSUMPTION (GALLONS)
JUN	14.84	58	13.90	8.83	6.01	6.01	0.09	72	127	30,444	27,769 E
JUL	14.53	60	13.40	8.77	5.76	5.76	0.14	73	127	29,559	26.899
AUG	13.68	65	12.27	8.91	4.77	4.77	0.14	72	127	26,946	24,538
SEP	21.38	63	20.71	13.54	7.84	7.84	0.18	73	109	68,514	62,785
OCT	13.82	63	13.36	8.70	5.12	5.12	0.16	71	128	28,221	26,094
NOV	9.39	31	8.72	2.86	6.53	6.53	0.29	70	115	23,336	20,317
DEC	7.27	21	6.63	1.56	5.71	5.71	0.37	67	115	16,547	15,114
JAN	9.96	16	9.27	1.57	8.39	8.39	0.38	66	111	24,835	22,669
FEB	9.44	28	8.83	2.66	6.78	6.78	0.34	65	106	26,013	23,921
MAR	8.64	21	7.92	1.84	6.80	6.80	0.37	67	100	28,438	26,081
APR	8.96	33	8.16	2.99	5.97	5.97	0.35	66	107	23,616	21,873
TOTAL	131.91	-	123.17	62.23	69.68	69.68	2.81	-	-	326,469	298,060
AVERAGE	11.99	47(1)	11.20	5.66	6.33	6.33	0.26	69	116	29,679	27,096

(1)Denotes Weighted Average.
E Denotes estimated value.

An increase in DHW demand occurred in September without a proportionally greater impact on the solar fraction; i.e., solar fraction remained at 63%. This implies that the solar DHW subsystem is capacity limited due to design or equipment size. If a larger capacity pump and preheat coil were used, the DHW solar fraction might have increased. Another improvement could be to simply have the cold water supply run through an immersed heat exchanger in the hot storage tank. This would save operating costs and might lower initial capital costs. A control problem with pump P4 caused the pump to operate almost continuously from December 1981 through April 1982. This problem increased the operating energy costs with very little additional benefit. Overall, the DHW subsystem performance was 47%.

The space heating performance for Oakmead Industries is presented in Tables 6 and 6a. The space heating load of 371.55 million BTU was satisfied by 187.04 million BTU of solar energy and 184.51 million BTU of auxiliary energy for a solar contribution of 50%. Solar energy provided a fossil fuel savings of 311.73 million BTU or 3,053 therms of natural gas.

Table 6. SPACE HEATING SUBSYSTEM

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(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 (%)	AMB TEMP (°F)
JUN	0.00	0.00	0.00	0.00	0	71
JUL	0.00	0.00	0.00	0.00	0	70
AUG	0.00	0.00	0.00	0.00	0	70
SEP	0.00	0.00	0.00	0.00	0	70
OCT	19.20	19.20	0.00	19.20	0	65
NOV	42.17	42.17	22.03	20.14	52	62
DEC	41.31	41.31	18.16	23.15	44	57
JAN	89.74	89.74	29.75	59.99	33	50
FEB	62.37	62.37	37.93	24.44	61	59
MAR	57.32	57.32	32.09	25.23	56	56
APR	59.44	59.44	47.08	12.36	79	60
TOTAL	371.55	371.55	187.04	184.51	-	-
AVERAGE	33.78	33.78	17.00	16.77	50(1)	63

(1)Denotes weighted average.

Table 6a. SPACE HEATING SUBSYSTEM (Continued)

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	MEASURED SOLAR ENERGY USED	TOTAL OPERATING ENERGY	SOLAR-SPECIFIC OPERATING ENERGY	AUXILIARY FOSSIL SAVINGS	AUXILIARY FOSSIL FUEL	HEATING DEGREE-DAYS
JUN	0.00	0.00	0.49	0.49	0.00	0.00	4
JUL	0.00	0.00	1.84	0.42	0.00	0.00	0
AUG	0.00	0.00	4.04	0.00	0.00	0.00	0
SEP	0.00	0.00	3.21	0.00	0.00	0.00	1
OCT	19.20	0.00	9.52	0.00	0.00	32.00	42
NOV	42.17	22.03	9.57	0.27	36.71	33.57	120
DEC	41.31	18.16	8.53	0.23	30.27	38.58	262
JAN	89.74	29.75	10.58	0.38	49.58	99.99	455
FEB	62.37	37.93	9.54	0.44	63.22	40.74	180
MAR	57.32	32.09	9.06	0.35	53.48	42.05	293
APR	59.44	47.08	8.90	0.42	78.47	20.60	178
TOTAL	371.55	187.04	75.28	3.00	311.73	307.53	1,535
AVERAGE	33.78	17.00	6.84	0.27	28.34	27.96	140

The space heating subsystem operated well, but the performance could have been better. Several problems lowered the space heating performance. The space heating time clocks caused the system to operate all day long in January and February 1982. This problem increased the space heating load which was primarily made up by auxiliary energy during the evening hours, and reduced the solar contribution to the DHW subsystem because the space heating subsystem has priority of solar utilization. From October 12, 1981 through November 6, 1981, no solar energy was used for space heating due to pump P2 not operating. The high heating subsystem operating energy from July 22 through November 6 is due to the continuous operation of the south zone fan.

Measured monthly values of the solar-specific operating energy for Oakmead Industries are shown in Table 7. 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 and fan power required to operate the entire solar system including the distribution fans in the conventional HVAC system. The solar-unique operating energy for Oakmead Industries is classified in three subsystems. The energy collection and storage subsystem incorporates pumps P1 and P3, the heat rejector fan, and the south zone collector fan. The space heating solar-specific operating energy is attributed to pump P2, and pump P4 is attributed to the DHW solar-specific operating energy. The ECSS solar operating energy accounted for 71% of the total solar-specific operating energy.

Table 7. SOLAR-SPECIFIC OPERATING ENERGY

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	DHW OPERATING ENERGY	SHS OPERATING ENERGY	TOTAL SOLAR OPERATING ENERGY
JUN	0.86	0.09	0.49	1.44
JUL	1.09	0.14	0.42	1.65
AUG	1.24	0.14	0.00	1.38
SEP	1.18	0.18	0.00	1.36
OCT	1.15	0.16	0.00	1.31
NOV	1.47	0.29	0.27	2.03
DEC	1.36	0.37	0.23	1.96
JAN	1.54	0.38	0.38	2.30
FEB	1.13	0.34	0.44	1.91
MAR	1.64	0.37	0.35	2.36
APR	1.31	0.35	0.42	2.08
TOTAL	13.97	2.81	3.00	19.78
AVERAGE	1.27	0.26	0.27	1.80

Energy savings for Oakmead Industries during the reporting period are presented in Table 8. The solar system provided a fossil fuel energy savings of 311.73 million BTU and an electrical energy savings of 42.45 million BTU. These energy savings are equivalent to 3,053 therms (305,310 cubic feet) of natural gas and 12,429 kwh of electric energy. The savings in dollars are $2,023.66 based on an actual fossil fuel rate of $0.50 per therm of natural gas and $0.04 per kwh of electrical energy.

Table 8. ENERGY SAVINGS

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING ELECTRICAL	SPACE HEATING FOSSIL FUEL	DOMESTIC HOT WATER ELECTRICAL	ECSS OPERATING ENERGY SOLAR-UNIQUE	NET ENERGY SAVINGS ELECTRICAL	NET ENERGY SAVINGS FOSSIL FUEL
JUN	8.83	-0.49	0.00	8.74	-0.86	7.39	0.00
JUL	8.77	-0.42	0.00	8.63	-1.09	7.12	0.00
AUG	8.91	0.00	0.00	8.77	-1.24	7.53	0.00
SEP	13.54	0.00	0.00	13.36	-1.18	12.18	0.00
OCT	8.70	0.00	0.00	8.54	-1.15	7.39	0.00
NOV	24.89	-0.27	36.71	2.57	-1.47	0.83	36.71
DEC	19.72	-0.23	30.27	1.19	-1.36	-0.40	30.27
JAN	31.32	-0.38	49.58	1.19	-1.54	-0.73	49.58
FEB	40.59	-0.44	63.22	2.32	-1.13	0.75	63.22
MAR	33.93	-0.35	53.48	1.47	-1.64	-0.52	53.48
APR	50.07	-0.42	78.47	2.64	-1.31	0.91	78.47
TOTAL	249.27	-3.00	311.73	59.42	-13.97	42.45	311.73
AVERAGE	22.66	-0.27	28.34	5.40	-1.27	3.86	28.34

Solar energy savings are realized whenever energy provided by the solar 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 or storage to the loads is subtracted from the solar energy contribution to the loads to determine net savings. The auxiliary gas-fired furnaces are considered to be 60% efficient for computing energy savings.

Summary weather conditions are presented in Table 9. The weather conditions were poorer than expected due to less sunshine during the heating season. The ambient temperature was 63°F versus the long-term average of 60°F. However, this temperature sensor could have been measuring some heat from roof convection due to its location.

Table 10 shows the insolation available on the vertical south-facing glass wall. This data represents the total potential sunshine on a vertical wall facing due south. Due to the overhang at Oakmead Industries, not all the insolation was available to the south-facing air collector subsystem.

Table 9. WEATHER CONDITIONS

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

MONTH	DAILY INCIDENT SOLAR* ENERGY PER UNIT AREA (BTU/FT^2-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
JUN	1,945	1,853	71	66	4	50	189	71
JUL	1,867	1,889	70	68	0	12	144	117
AUG	1,864	1,897	70	68	0	15	158	111
SEP	1,759	1,907	70	68	1	13	164	94
OCT	1,602	1,687	65	63	42	90	45	19
NOV	1,037	1,365	62	56	120	276	19	0
DEC	798	1,157	57	50	262	456	0	0
JAN	1,170	1,203	50	50	455	481	0	0
FEB	1,388	1,484	59	53	180	350	5	0
MAR	1,257	1,762	56	55	293	322	0	0
APR	1,706	1,897	60	58	178	228	19	12
TOTAL	-	-	-	-	1,535	2,293	743	424
AVERAGE	1,490	1,646	63	60	140	208	68	39

*Liquid collector subsystem at 45 degree tilt.

Table 10. VERTICAL-SOUTH WALL INSOLATION DATA

OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

MONTH	INCIDENT SOLAR* RADIATION (MILLION BTU)	DAILY INCIDENT* SOLAR ENERGY PER UNIT AREA (BTU/FT^2-DAY)
JUN	29.49	587
JUL	32.89	633
AUG	38.94	750
SEP	46.76	931
OCT	60.01	1,156
NOV	46.33	922
DEC	39.37	758
JAN	57.27	1,103
FEB	52.01	1,109
MAR	40.37	778
APR	39.04	777
TOTAL	482.48	-
AVERAGE	43.86	864

*Air collector subsystem at 90 degree tilt.

1.2 SYSTEM OPERATION

1.2.1 TYPICAL SYSTEM OPERATION

April 16, 1982 represents a sunny day of solar system operation. The variation of key solar system parameters for this day is presented in Figures 3a, 3b, and 3c. This day is representative of solar system operation during the entire reporting period, except when the collector pump was operating all day long.

Figure 3a shows the intensity of solar radiation on the collector array during the day. The figure depicts excellent sunshine throughout the day with a maximum intensity of 320 BTU/ft^2-hr. The insolation is measured at a collector orientation of 45 degrees to the horizontal. The collector operating period is shown on the insolation curve.

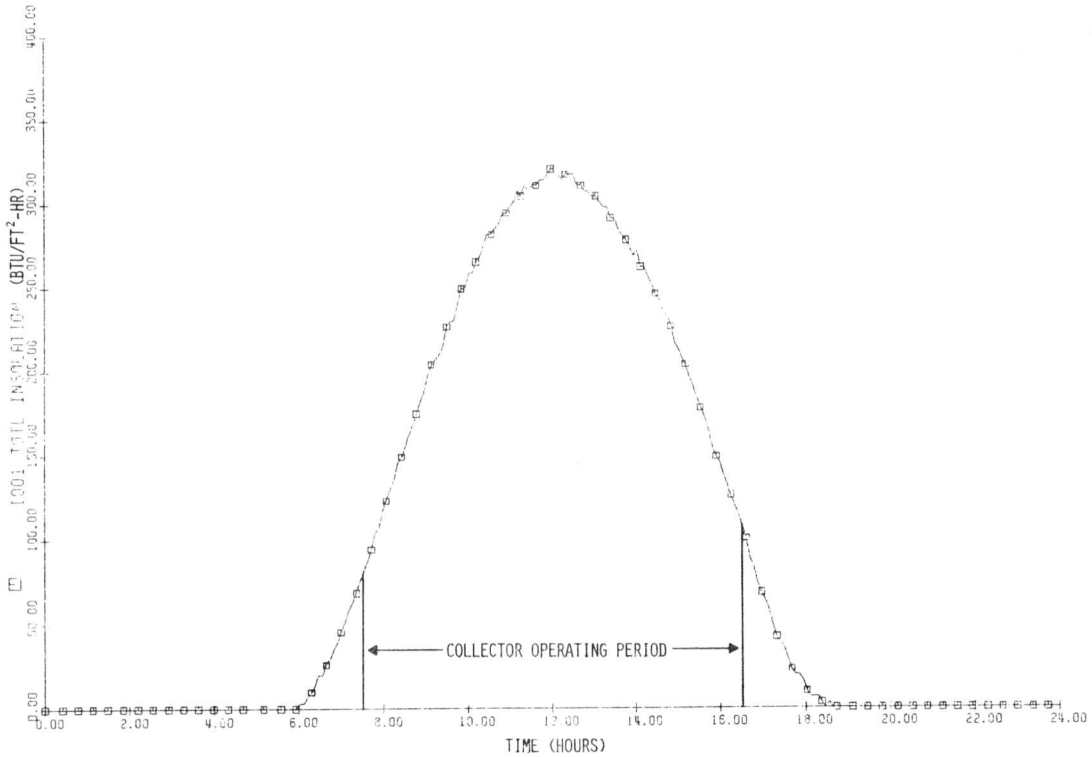


Figure 3a. Typical Insolation Data
Oakmead Industries
April 16, 1982

The collector array inlet and outlet temperature profile is presented in Figure 3b. The collector pump was activated at 0722 hours when the collector absorber plate temperature was higher than the temperature in the Thermal Control Loop (TCL). (Refer to System Description in Appendix A.) The temperature differential between the collector inlet and outlet is small during startup conditions and the curves show a negative differential soon after startup. However, the temperature increases very rapidly and so does the collector temperature differential after startup. But, at 0946 hours, the flow to storage stops and results in a decrease in the collector inlet and outlet temperature differential.

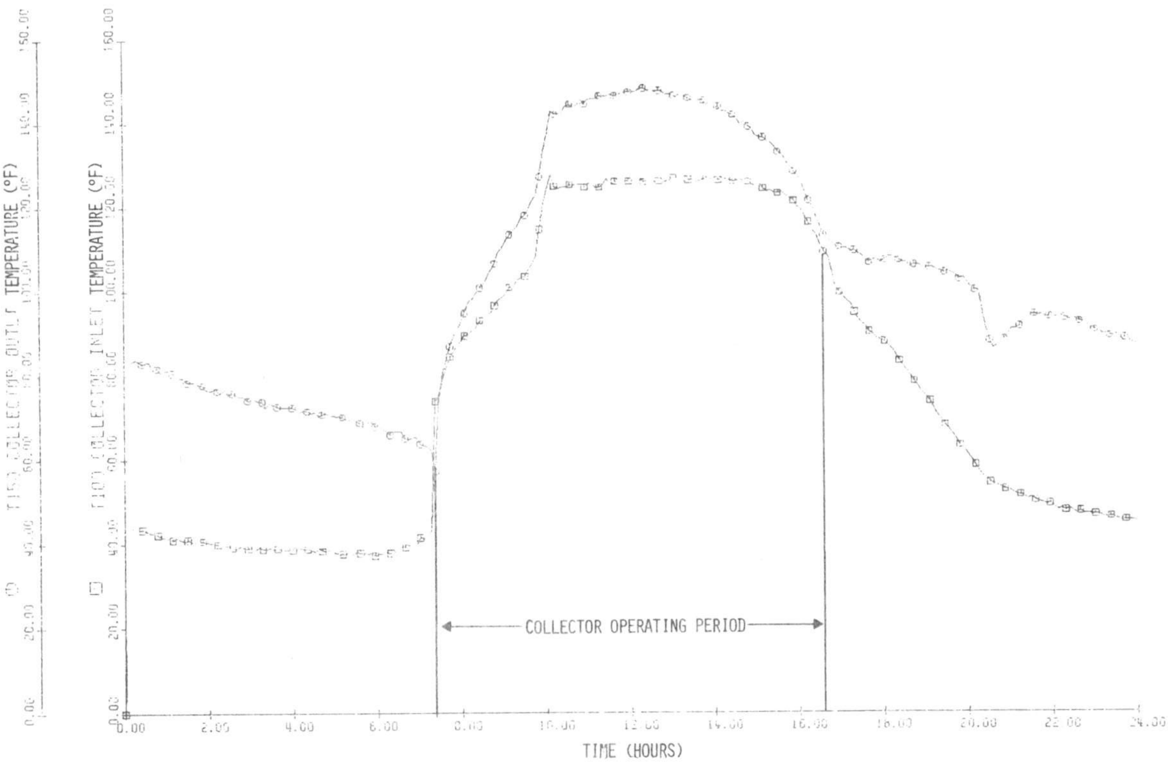


Figure 3b. Typical Collector Array Temperatures, Inlet/Outlet
Oakmead Industries
April 16, 1982

At 1012 hours, storage flow starts again and causes the collector inlet and outlet differential to increase. The collector array temperature difference is very high now and illustrates good collector performance. The collector pump is deactivated at 1636 hours when the collector temperature difference decreases below the set point. The collector pump operating period is shown in this figure.

The storage tank temperatures are illustrated in Figure 3c. The storage tank shows very little stratification except during addition of solar energy from the collector array. From midnight to 0337 hours, energy was removed from storage to the space heating and DHW subsystems. Between 0337 hours and 0748 hours, only a small amount of energy was lost from the storage tank. Solar energy was added to the storage tank from 0748 hours to 0946 hours and from 1007 hours to 1838 hours. The tank temperature rose to a maximum of 113°F. Note that the middle tank temperature is greater than the top tank temperature during additions of solar energy to storage. This higher temperature occurs because solar energy always enters into the middle of the storage tank exactly where temperature sensor T203 is located. The sensor indicates the fluid temperature prior to mixing with the remaining fluid. From 1636 hours to midnight, solar energy is again used for the space heating and DHW subsystems. The storage performance is very highly dependent on the performance of control valves AV1 and AV2.

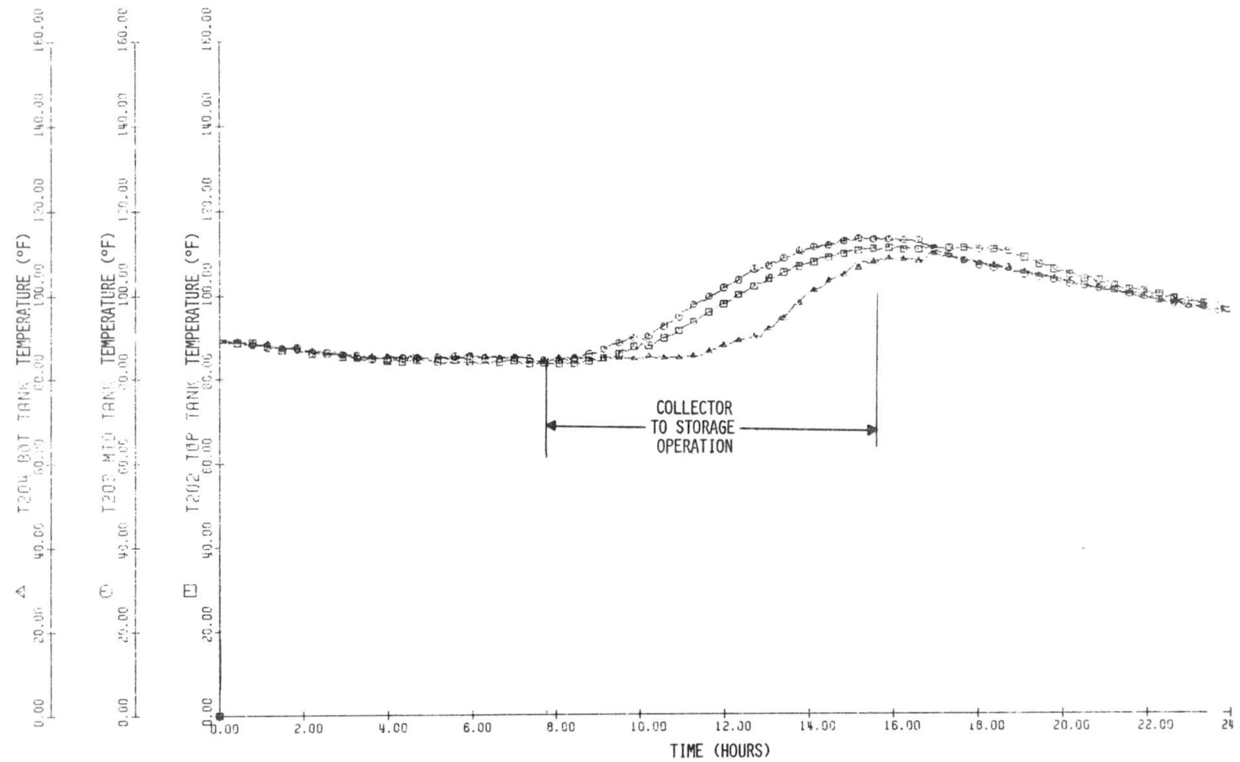


Figure 3c. Typical Storage Fluid Temperatures
Oakmead Industries
April 16, 1982

1.2.2 SYSTEM OPERATING SEQUENCE

Figure 4 is a bar chart depicting the system operating sequence for April 16, 1982. This data correlates with the curves shown in Figures 3a, 3b, and 3c and provides some additional insight into those curves.

There are several observations to be made from Figure 4. The collector to storage flow is regulated by modulating valve AV2 and does not supply flow to storage at all times. Due to the temperature control loop (refer to Appendix A), solar energy can be delivered from the collector heat exchanger directly to the space heating load. This design feature enhances the system performance because solar energy can be used directly. The space heating load is satisfied by a combination of solar and auxiliary energy. Due to a control problem with pump P4, the pump was on at all times. Also, the electric resistance heater in the DHW tank operates most of the time to maintain the DHW tank at its internal set point temperature. The DHW usage pattern shows that most of the hot water is used during the day with sporadic usage in the evening and morning hours. The DHW usage is related to occupancy of the building.

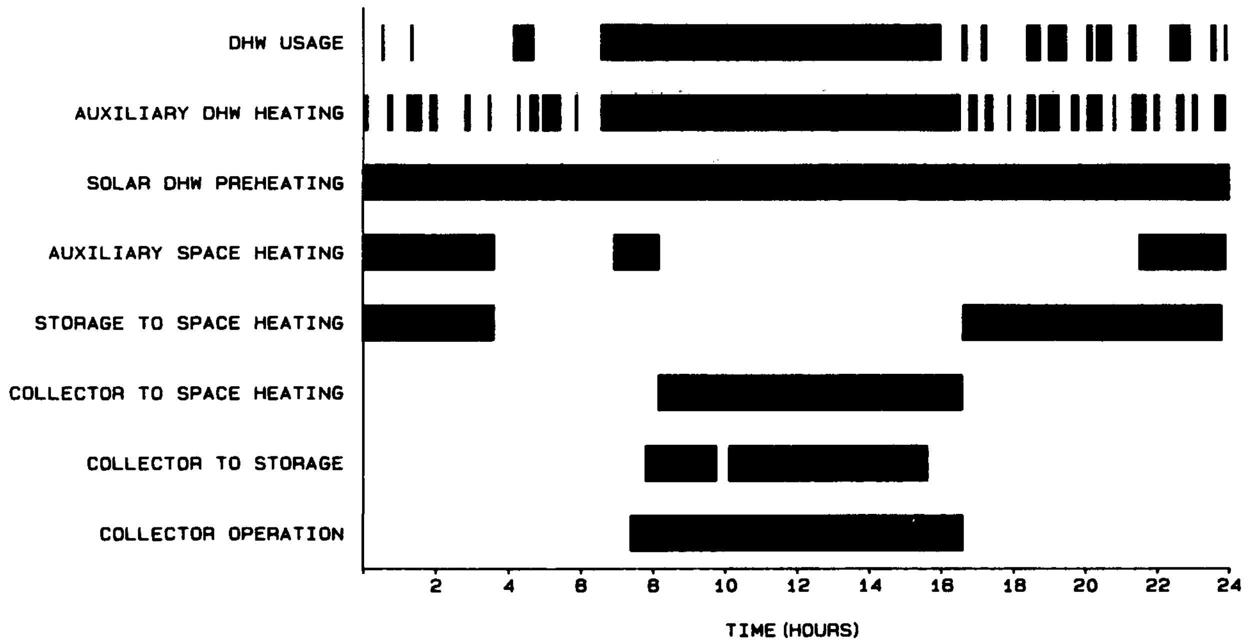


Figure 4. Typical System Operating Sequence
Oakmead Industries
April 16, 1982

1.3 SOLAR ENERGY UTILIZATION

The utilization of solar energy and the percentage of losses are shown in Figure 5. Solar energy was collected very efficiently, but due to high losses during DHW preheating only 49% of the collected solar energy was used for the system loads. A total of 19% of the incident solar radiation was utilized to meet the load.

The Oakmead Industries solar energy system performed exceptionally well during this eleven-month period from June 1981 to April 1982. It is unlikely that the system will be able to meet design expectations because most of the solar energy losses occurred during the summer when there was only a DHW load. However, modifications to the solar energy system should be made to improve the summer performance of the solar DHW subsystem.

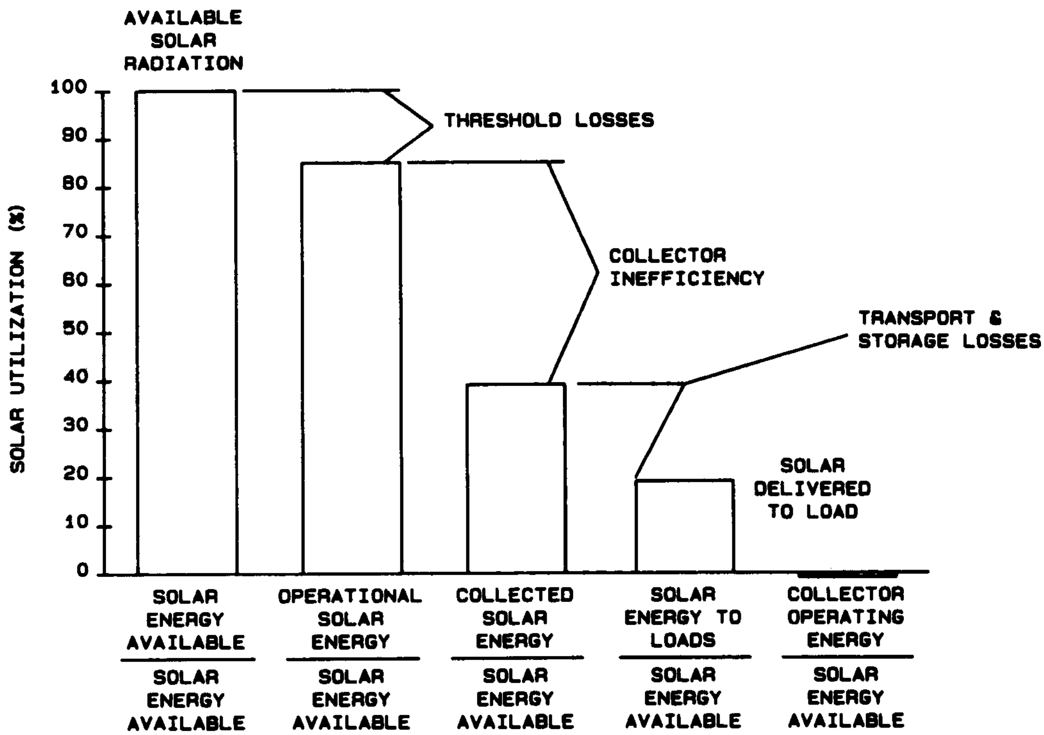


Figure 5. Solar Energy Use
Oakmead Industries
June 1981 through April 1982

SECTION 2

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

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

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

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

*5A. User's Guide to Monthly Performance Reports, November 1981, SOLAR/0004-80/18, Vitro Laboratories, Silver Spring, Maryland.

*5B. Instrumentation Installation Guidelines, March 1981, Parts 1, 2, and 3, SOLAR/0001-81/15, Vitro Laboratories, Silver Spring, Maryland.

6. Solar Energy System Performance Evaluation, Oakmead Industries, October 1980 through May 1981, SOLAR/2076-81/14, Vitro Laboratories, Silver Spring, Maryland.

7. Monthly Performance Report, Oakmead Industries, June 1981, Vitro Laboratories, Silver Spring, Maryland.

8. Monthly Performance Report, Oakmead Industries, July 1981, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, Oakmead Industries, August 1981, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, Oakmead Industries, September 1981, Vitro Laboratories, Silver Spring, Maryland.

11. Monthly Performance Report, Oakmead Industries, October 1981, Vitro Laboratories, Silver Spring, Maryland.

12. Monthly Performance Report, Oakmead Industries, November 1981, 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.

13. Monthly Performance Report, Oakmead Industries, December 1981, Vitro Laboratories, Silver Spring, Maryland.

14. Monthly Performance Report, Oakmead Industries, January 1982, Vitro Laboratories, Silver Spring, Maryland.

15. Monthly Performance Report, Oakmead Industries, February 1982, Vitro Laboratories, Silver Spring, Maryland.

16. Monthly Performance Report, Oakmead Industries, March 1982, Vitro Laboratories, Silver Spring, Maryland.

17. Monthly Performance Report, Oakmead Industries, April 1982, Vitro Laboratories, Silver Spring, Maryland.

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.

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 degrees 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, deenergizes 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.)

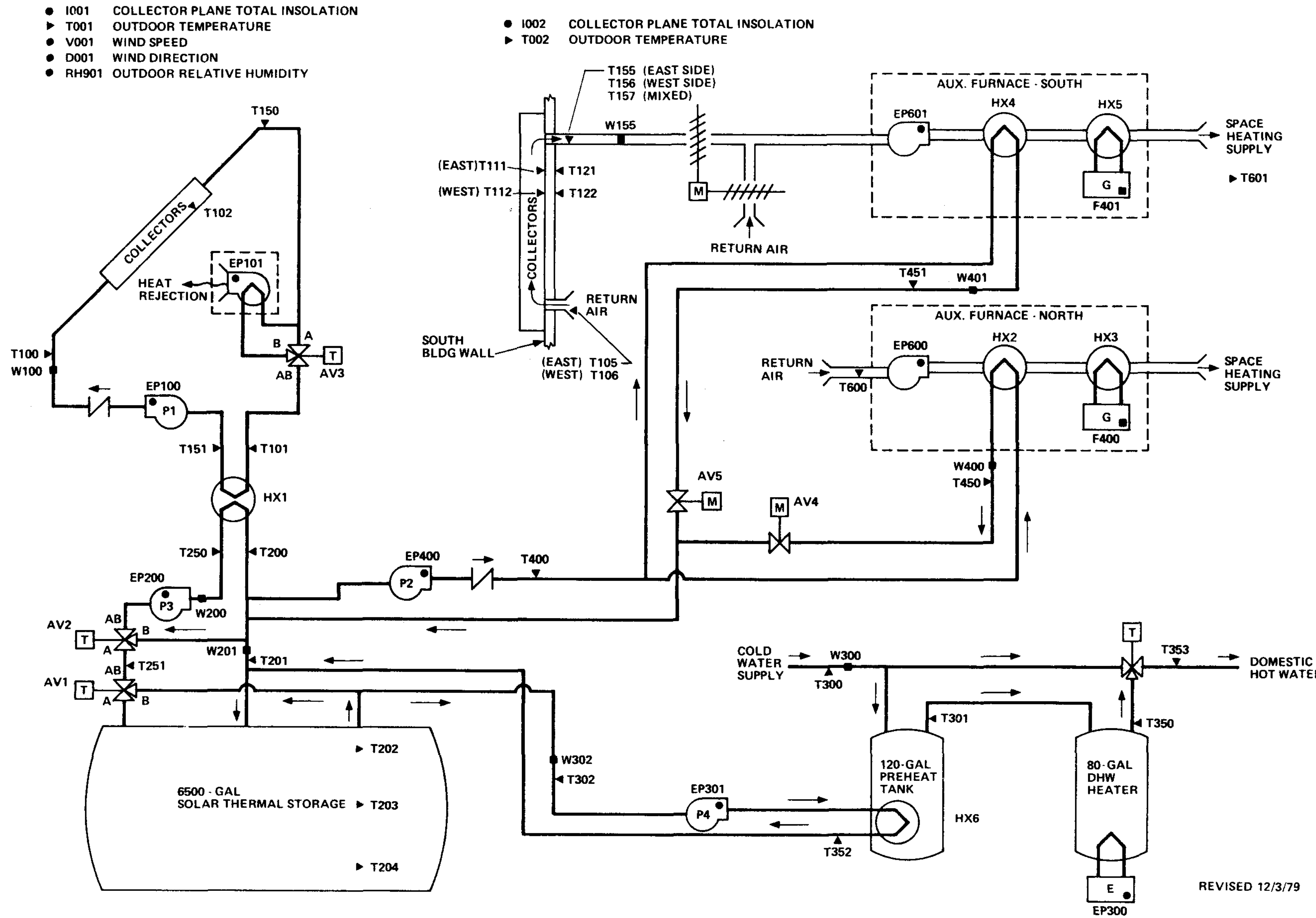

Figure A-1. Oakmead Industries Solar Energy System Schematic

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.

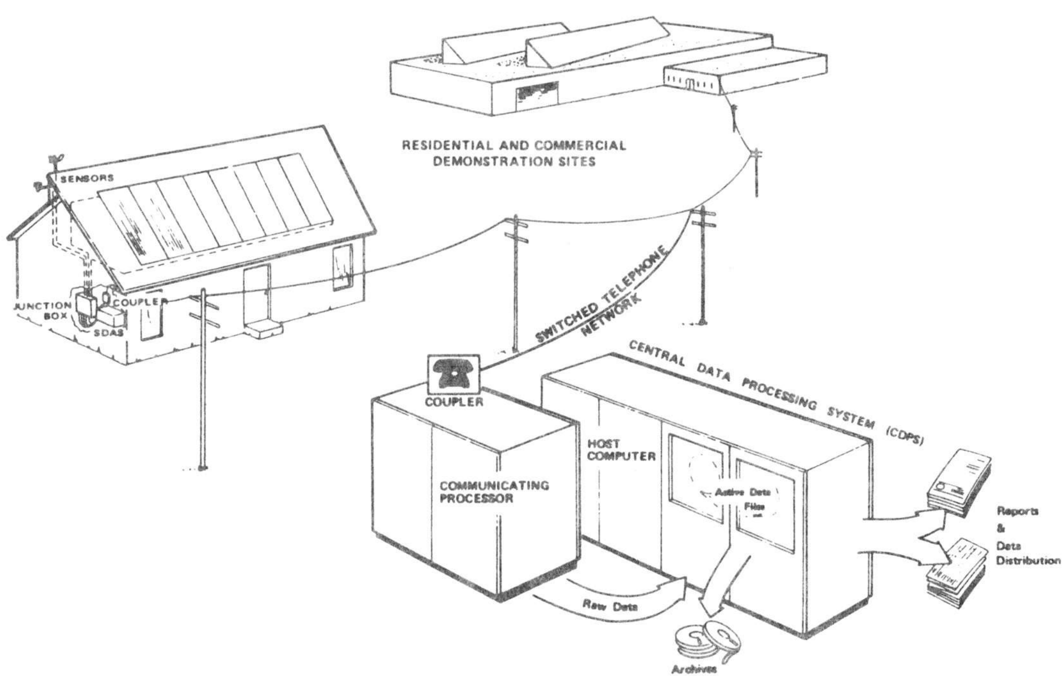

Figure B-1. The National Solar Data Network

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

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

DATA ANALYSIS

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

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

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

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

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

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

REPORTING

The performance of the Oakmead Industries solar energy system from June 1981 through April 1982 was analyzed and Monthly Performance Reports were prepared. 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
January 1981
February 1981
March 1981
April 1981
May 1981
June 1981
July 1981
August 1981
September 1981
October 1981
November 1981
December 1981
January 1982
February 1982
March 1982
April 1982

Solar Energy System Performance Evaluation:

*October 1980 through May 1981, SOLAR/2076-81/14

* These reports can be obtained by contacting: U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, TN 387830.

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.
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.
CLEF	Collector Array Efficiency	Ratio of the collected solar energy to the incident solar energy.
COPE	SCS Operating Energy	Amount of energy required to support the SCS operation which is not intended to be applied directly to the SCS load.
CSAUX	Auxiliary Energy to ECSS	Amount of auxiliary energy supplied to the ECSS.
* CSCEF	ECSS Solar Conversion Efficiency	Ratio of the solar energy supplied from the ECSS to the load subsystems to the incident solar energy on the collector array.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
CSE	Solar Energy to SCS	Amount of solar energy delivered to the SCS.
CSEO	Energy Delivered from ECSS to Load Subsystems	Amount of energy supplied from the ECSS to the load subsystems (including any auxiliary energy supplied to the ECSS).
* CSFR	SCS Solar Fraction	Portion of the SCS load which is supported by solar energy.
CSOPE	ECSS Operating Energy	Amount of energy used to support the ECSS operation (which is not intended to be supplied to the ECSS thermal state).
CSRJE	ECSS Rejected Energy	Amount of energy intentionally rejected or dumped from the ECSS subsystem.
* CSVE	SCS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SCS and the actual electrical energy required to support the demonstration SCS, for identical SCS loads.
* CSVF	SCS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SCS and the actual fossil energy required to support the demonstration SCS, for identical loads.
HAE	SHS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SHS to be converted and applied to the SHS load.
HAF	SHS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SHS to be converted and applied to the SHS load.
HAT	SHS Auxiliary Thermal Energy	Amount of energy provided to the SHS by a heat transfer fluid from an auxiliary source.
* HL	Space Heating Subsystem Load	Energy required to satisfy the temperature control demands of the space heating subsystem.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
HOPE	SHS Operating Energy	Amount of energy required to support the SHS operation (which is not intended to be applied directly to the SHS load).
HOURCT	Record Time	Count of hours elapsed from the start of 1977.
* HSFR	SHS Solar Fraction	Portion of the SHS load which is supported by solar energy.
HSE	Solar Energy to SHS	Amount of solar energy delivered to the SHS.
* HSVE	SHS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SHS and the actual electrical energy required to support the demonstration SHS, for identical SHS loads.
* HSVF	SHS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SHS and the actual fossil energy required to support the demonstration SHS, for identical SHS loads.
HWAE	HWS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the HWS to be converted and applied to the HWS load.
HWAF	HWS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the HWS to be converted and applied to the HWS load.
HWAT	HWS Auxiliary Thermal Energy	Amount of energy provided to the HWS by a heat transfer fluid from an auxiliary source.
HWCSM	Service Hot Water Consumption	Amount of heated water delivered to the load from the hot water subsystem.
* HWL	Hot Water Subsystem Load	Amount of energy supplied to the HWS.
* HWDM	Hot Water Demand	Energy required to satisfy the temperature control demands of the building service hot water system.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
HWOPE	HWS Operating Energy	Amount of energy required to support the HWS operation which is not intended to be applied directly to the HWS load.
HWSE	Solar Energy to HWS	Amount of solar energy delivered to the HWS.
* HWSFR	HWS Solar Fraction	Portion of the HWS load which is supported by solar energy.
* HWSVE	HWS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional HWS and the actual electrical energy required to support the demonstration HWS, for identical HWS loads.
* HWSVF	HWS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional HWS and the actual fossil energy required to support the demonstration HWS, for identical loads.
RELH	Relative Humidity	Average outdoor relative humidity at the site.
* SE	Incident Solar Energy	Amount of solar energy incident upon one square foot of the collector plane.
SEA	Incident Solar Energy on Array	Amount of solar energy incident upon the collector array.
* SEC	Collector Solar Energy	Amount of thermal energy added to the heat transfer fluid for each square foot of the collector area.
* SECA	Collected Solar Energy by Array	Amount of thermal energy added to the heat transfer fluid by the collector array.
SEDF	Diffuse Insolation	Amount of diffuse solar energy incident upon one square foot of a collector plane.
SEOP	Operational Incident Solar Energy	Amount of incident solar energy upon the collector array whenever the collector loop is active.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
* SEL	Solar Energy to Load Subsystems	Amount of solar energy supplied by the ECSS to all load subsystems.
* SFR	Solar Fraction of System Load	Portion of the system load which was supported by solar energy.
STECH	Change in ECSS Stored Energy	Change in ECSS stored energy during reference time period.
STEFF	ECSS Storage Efficiency	Ratio of the sum of energy supplied by ECSS storage and the change in ECSS stored energy to the energy delivered to the ECSS storage.
STEI	Energy Delivered to ECSS Storage	Amount of energy delivered to ECSS storage by the collector array and from auxiliary sources.
STEO	Energy Supplied by ECSS Storage	Amount of energy supplied by ECSS storage to the load subsystems.
STOCAP	Storage Tank Capacity	Volume of storage tank in gallons.
* 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.
Controlled Delivered Energy	The heating load derived from the summation of measured solar and auxiliary components.
Cooling Degree-Days	The sum over a specified period of time of the number of degrees the average daily temperature is <u>above</u> 65°F.
Cooling Tower	A heat exchanger that transfers waste heat to outside ambient air.
Diffuse Radiation	Solar Radiation which is scattered by air molecules, dust, or water droplets and incapable of being focused.
Drain Down	An arrangement of sensors, valves and actuators to automatically drain the solar collectors and collector piping to prevent freezing in the event of cold weather.
Duct Heating Coil	A liquid-to-air heat exchanger in the duct distribution system.
Effective Heat Transfer Coefficient	The heat transfer coefficient, per unit plate area of a collector, which is a measure of the total heat losses per unit area from all sides, top, back, and edges.
Energy Gain	The thermal energy gained by the collector transfer fluid. The thermal energy output of the collector.

Energy Savings	The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.
Expansion Tank	A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as 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:

$$\frac{Ti-Ta}{I}\ \left(\frac{°F \times hr. \times sq.\ ft.}{BTU}\right)$$

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 parameter 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 Contribution of Load	The portion of total load actually met by solar energy.
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.
Solar-Unique Operating Energy	Operating energy which is expended on the solar system.
Storage Efficiency, N_s	Measure of effectiveness of transfer of energy through the storage subsystem taking into account system losses.
Storage Subsystem	The assembly of components used to store solar-source energy for use during periods of low insolation.
Stratification	A phenomenon that causes a distinct thermal gradient in a heat transfer fluid, in contrast to a thermally homogeneous fluid. Results in the layering of the heat transfer fluid, with each layer at a different temperature. In solar energy systems, stratification can occur in liquid storage tanks or rock beds, and may even occur in pipes and ducts. The temperature gradient or layering may occur in a horizontal, vertical or radial direction.
System Performance Factor	Ratio of system load to the total equivalent fossil energy expended or required to support the system load.
Ton of Refrigeration	The heat equivalent to the melting of one ton (2,000 pounds) of ice at 32°F in 24 hours. A ton of refrigeration will absorb 12,000 BTU/hr, or 288,000 BTU/day.
Tracking Collector	A solar collector that moves to point in the direction of the sun.
Zone	A portion of a conditioned space that is controlled to meet heating or cooling requirements separately from the other space or other zones.

SECTION 3. GENERAL ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineering.
BTU	British Thermal Unit, a measure of heat energy. The quantity of heat required to raise the temperature of one pound of pure water one Fahrenheit degree. One BTU is equivalent to 2.932×10^{-4} kwh of electrical energy.
COP	Coefficient of Performance. The ratio of total load to solar-source energy.
DHW	Domestic Hot Water.
ECSS	Energy Collection and Storage System.
HWS	Domestic or Service Hot Water Subsystem.
KWH	Kilowatt Hours, a measure of electrical energy. The product of kilowatts of electrical power applied to a load times the hours it is applied. One kwh is equivalent to 3,413 BTU of heat energy.
NSDN	National Solar Data Network.
SCS	Space Cooling Subsystem.
SHS	Space Heating Subsystem.
SOLMET	Solar Radiation/Meteorology Data.

APPENDIX D

PERFORMANCE EQUATIONS

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

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

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

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

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

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

For a liquid system ΔH is generally given by

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

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

* See Appendix B.

For an air system ΔH is generally given by

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

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

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

For electrical power, a general example is

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

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

Letter Designations

C or CP	=	Specific Heat
D	=	Direction or Position
DS	=	Discrete Switch Position
EE	=	Electric Energy
EP	=	Electric Power
ET	=	Elapsed Time of Operation
F	=	Fuel Flow Rate
H	=	Enthalpy
HR	=	Humidity Ratio
HWD	=	Functional procedure to calculate the enthalpy change of water at the average of the inlet and outlet temperatures
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
WT	=	Total Volume Flow
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)

$$SEOP = (1/60) \times \Sigma \left[I001 \times CLAREA \right] \times \Delta\tau$$

when the collector loop is activated

SOLAR ENERGY COLLECTED BY THE ARRAY - LIQUID SYSTEM (BTU)

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

REJECTED SOLAR ENERGY (BTU)

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

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)

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

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

$CLEFOP = SECA/SEOP$

STORAGE SUBSYSTEM

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-FT^2-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)

$$HWDM = \Sigma\ (M300 \times CP \times (T353 - T33)) \times \Delta\tau$$

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 x T300)/M300

IF M300 = 0 then TSW = TWS_P

SUPPLY HOT WATER TEMPERATURE (°F)

THW = (M300 x T353)/M300

if M300 = 0 then THW = THW_P

HOT WATER DEMAND SOLAR FRACTION (BTU)

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

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

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

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

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

SPACE HEATING AUX THERMAL ENERGY (BTU)

HAT = HAF x 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

SYSTEM FACTORS

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)]

OAKMEAD INDUSTRIES LONG-TERM DATA (LIQUID SUBSYSTEM)

COLLECTOR TILT: 45.0 DEGREES
LATITUDE: 37.4 DEGREES

LOCATION: SANTA CLARA, CALIFORNIA
COLLECTOR AZIMUTH: 0.0 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1466.	708.	0.48300	1.699	1203.	481	0	50.
FEB	1919.	1018.	0.53027	1.458	1484.	350	0	53.
MAR	2494.	1456.	0.58394	1.210	1762.	322	0	55.
APR	3078.	1921.	0.62415	0.987	1897.	228	12	58.
MAY	3477.	2212.	0.63627	0.847	1873.	123	20	62.
JUN	3635.	2349.	0.64619	0.789	1853.	50	71	66.
JUL	3549.	2323.	0.65442	0.813	1889.	12	117	68.
AUG	3226.	2054.	0.63660	0.924	1897.	15	111	68.
SEP	2701.	1700.	0.62939	1.122	1907.	13	94	68.
OCT	2084.	1213.	0.58194	1.391	1687.	90	19	63.
NOV	1570.	822.	0.52367	1.660	1365.	276	0	56.
DEC	1340.	645.	0.48152	1.793	1157.	456	0	50.

LEGEND:

HOBAR ==> MONTHLY AVERAGE DAILY EXTRATERRESTRIAL RADIATION (IDEAL) IN BTU/DAY-FT2.
HBAR ==> MONTHLY AVERAGE DAILY RADIATION (ACTUAL) IN BTU/DAY-FT2.
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 * HBAR) IN BTU/DAY-FT2.
HDD ==> NUMBER OF HEATING DEGREE DAYS PER MONTH.
CDD ==> NUMBER OF COOLING DEGREE DAYS PER MONTH.
TBAR ==> AVERAGE AMBIENT TEMPERATURE IN DEGREES FAHRENHEIT.

OAKMEAD INDUSTRIES LONG-TERM DATA (AIR SUBSYSTEM)

COLLECTOR TILT: 90.0 DEGREES
LATITUDE: 37.4 DEGREES

LOCATION: SANTA CLARA, CALIFORNIA
COLLECTOR AZIMUTH: 0.0 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1466.	708.	0.48300	1.575	1115.	481	0	50.
FEB	1919.	1018.	0.53027	1.222	1243.	350	0	53.
MAR	2494.	1456.	0.58394	0.859	1251.	322	0	55.
APR	3078.	1921.	0.62415	0.551	1059.	228	12	58.
MAY	3477.	2212.	0.63627	0.389	862.	123	20	62.
JUN	3635.	2349.	0.64619	0.332	781.	50	71	66.
JUL	3549.	2323.	0.65442	0.353	820.	12	117	68.
AUG	3226.	2054.	0.63660	0.473	972.	15	111	68.
SEP	2701.	1700.	0.62939	0.726	1234.	13	94	68.
OCT	2084.	1213.	0.58194	1.115	1353.	90	19	63.
NOV	1570.	822.	0.52367	1.509	1241.	276	0	56.
DEC	1340.	645.	0.48152	1.707	1102.	456	0	50.

LEGEND:

HOBAR ==> MONTHLY AVERAGE DAILY EXTRATERRESTRIAL RADIATION (IDEAL) IN BTU/DAY-FT2.
HBAR ==> MONTHLY AVERAGE DAILY RADIATION (ACTUAL) IN BTU/DAY-FT2.
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 * HBAR) IN BTU/DAY-FT2.
HDD ==> NUMBER OF HEATING DEGREE DAYS PER MONTH.
CDD ==> NUMBER OF COOLING DEGREE DAYS PER MONTH.
TBAR ==> AVERAGE AMBIENT TEMPERATURE IN DEGREES FAHRENHEIT.

APPENDIX F

FLUID SAMPLE ANALYSIS

The purpose of the chemical analysis of antifreeze solutions is to identify three characteristics of the liquid: (1) the thermal properties, (2) the freezing point, and (3) the occurrence or likelihood of corrosion. The percent and type of antifreeze affect the first two characteristics. In general, the glycol concentration should be somewhere in the range of 50% to give a freezing point of -37°F for ethylene glycol and -25°F for propylene glycol. This percentage of glycol also insures proper corrosion protection, because corrosion inhibitor concentrations are designed for this concentration.

The corrosivity of a liquid is hard to evaluate quantitatively. In general:

1. pH should be between 7.5 and 9.0.

2. Reserve alkalinity varies with antifreeze manufacturer. The alkalinity might range from eight to 25 for fresh antifreezes. With time, the alkalinity tends to decrease and, if it reaches zero, then the liquid can rapidly turn acidic (i.e., pH less than seven). This is very undesirable.

3. Chloride concentration should be less than 50 ppm.

Presence of other components is indicative of type of antifreeze, type of water, and products of corrosion. Presence of silicon is generally indicative of automotive antifreeze, and a requirement to change the liquid at two-year intervals. Presence of ash, calcium, and magnesium indicate minerals in water and possibility of scaling. Copper, iron, or aluminum indicate that these metals in the system might be corroding.

The sample of the Oakmead Industries collector fluid was taken on November 4, 1980, and the following analysis is included:

pH	7.6
Reserve Alkalinity	0.2
Propylene Glycol (%)	6.2
Sodium (ppm)	20
Calcium (ppm)	21
Magnesium (ppm)	19
Chlorides (ppm)	18
Sulfates (ppm)	5

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 1982

SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM P2736R

GENERAL SITE DATA:	CONVENTIONAL UNITS
INCIDENT SOLAR ENERGY	173.220 MILLION BTU
	N.A. BTU/SQ.FT.
COLLECTED SOLAR ENERGY	61.395 MILLION BTU
	N.A. BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	82 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.354
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	N.A.
AVERAGE AMBIENT TEMPERATURE	N.A. DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.29
ECSS OPERATING ENERGY	1.309 MILLION BTU
ECSS PERFORMANCE FACTOR	11653 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	10.558 MILLION BTU
TOTAL ENERGY CONSUMED	98.522 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	833 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	305 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	8.961	59.441	N.A.	68.402 MILLION BTU
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR SAVINGS RATIO	N.A.	N.A.	N.A.	N.A.
SOLAR ENERGY USED	2.995	47.080	N.A.	50.074 MILLION BTU
OPERATING ENERGY	0.347	8.901	N.A.	10.558 MILLION BTU
AUX. THERMAL ENERGY	5.966	12.362	N.A.	18.328 MILLION BTU
AUX. ELECTRIC FUEL	5.966	N.A.	N.A.	5.966 MILLION BTU
AUX. FOSSIL FUEL	N.A.	20.603	N.A.	20.603 MILLION BTU
ELECTRICAL SAVINGS	2.648	-0.426	N.A.	0.912 MILLION BTU
FOSSIL SAVINGS	N.A.	78.466	N.A.	78.466 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.00

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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MONTHLY REPORT: APRIL 1982

SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM P2736R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	173.220 MILLION BTU
	N.A. BTU/SQ.FT.
COLLECTED SOLAR ENERGY	61.395 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	0.29
ECSS OPERATING ENERGY	1.309 MILLION BTU
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	10.558 MILLION BTU
TOTAL ENERGY CONSUMED	98.522 MILLION BTU

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	8.961	59.441	N.A.	68.402 MILLION BTU
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR ENERGY USED	2.995	47.080	N.A.	50.074 MILLION BTU
OPERATING ENERGY	0.347	8.901	N.A.	10.558 MILLION BTU
AUX. THERMAL ENERGY	5.966	12.362	N.A.	18.328 MILLION BTU
AUX. ELECTRIC FUEL	5.966	N.A.	N.A.	5.966 MILLION BTU
AUX. FOSSIL FUEL	N.A.	20.603	N.A.	20.603 MILLION BTU
ELECTRICAL SAVINGS	2.648	-0.426	N.A.	0.912 MILLION BTU
FOSSIL SAVINGS	N.A.	78.466	N.A.	78.466 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.90

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.00

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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MONTHLY REPORT: APRIL 1982

SITE SUMMARY: OAKMEAD INDUSTRIES - COMBINED SYSTEM P2736R

	SI UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	182.747 GIGA JOULES
	N.A. KJ/SQ.M.
COLLECTED SOLAR ENERGY	64.772 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	0.29
ECSS OPERATING ENERGY	1.381 GIGA JOULES
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	11.139 GIGA JOULES
TOTAL ENERGY CONSUMED	103.940 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	9.454	62.711	N.A.	72.164 GIGA JOULES
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR ENERGY USED	3.159	49.669	N.A.	52.829 GIGA JOULES
OPERATING ENERGY	0.366	9.391	N.A.	11.139 GIGA JOULES
AUX. THERMAL ENG	6.294	13.042	N.A.	19.336 GIGA JOULES
AUX. ELECTRIC FUEL	6.294	N.A.	N.A.	6.294 GIGA JOULES
AUX. FOSSIL FUEL	N.A.	21.736	N.A.	21.736 GIGA JOULES
ELECTRICAL SAVINGS	2.793	-0.450	N.A.	0.962 GIGA JOULES
FOSSIL SAVINGS	N.A.	82.782	N.A.	82.782 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.90

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.00

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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MONTHLY REPORT: APRIL 1982

SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	134.178 MILLION BTU
	51174 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	61.395 MILLION BTU
	23415 BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	82 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.458
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	0.488
AVERAGE AMBIENT TEMPERATURE	58 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.37
ECSS OPERATING ENERGY	1.309 MILLION BTU
ECSS PERFORMANCE FACTOR	19098 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	10.558 MILLION BTU
TOTAL ENERGY CONSUMED	98.522 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	1273 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	466 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	8.961	59.441	N.A.	68.402 MILLION BTU
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR SAVINGS RATIO	0.321	0.788	N.A.	0.726
SOLAR ENERGY USED	2.995	47.080	N.A.	50.074 MILLION BTU
OPERATING ENERGY	0.347	8.901	N.A.	10.558 MILLION BTU
AUX. THERMAL ENERGY	5.966	12.362	N.A.	18.328 MILLION BTU
AUX. ELECTRIC FUEL	5.966	N.A.	N.A.	5.966 MILLION BTU
AUX. FOSSIL FUEL	N.A.	20.603	N.A.	20.603 MILLION BTU
ELECTRICAL SAVINGS	2.648	-0.426	N.A.	0.912 MILLION BTU
FOSSIL SAVINGS	N.A.	78.466	N.A.	78.466 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.02

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
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MONTHLY REPORT: APRIL 1982
SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	134.178 MILLION BTU
	51174 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	61.395 MILLION BTU
	23415 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	58 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.37
ECSS OPERATING ENERGY	1.309 MILLION BTU
STORAGE EFFICIENCY	122.80 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	1.836 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	10.558 MILLION BTU
TOTAL ENERGY CONSUMED	98.522 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	8.961	59.441	N.A.	68.402 MILLION BTU
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR ENERGY USED	2.995	47.080	N.A.	50.074 MILLION BTU
OPERATING ENERGY	0.347	8.901	N.A.	10.558 MILLION BTU
AUX. THERMAL ENERGY	5.966	12.362	N.A.	18.328 MILLION BTU
AUX. ELECTRIC FUEL	5.966	N.A.	N.A.	5.966 MILLION BTU
AUX. FOSSIL FUEL	N.A.	20.603	N.A.	20.603 MILLION BTU
ELECTRICAL SAVINGS	2.648	-0.426	N.A.	0.912 MILLION BTU
FOSSIL SAVINGS	N.A.	78.466	N.A.	78.466 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.90
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.02

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

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

MONTHLY REPORT: APRIL 1982
SITE SUMMARY: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	141.558 GIGA JOULES
	581134 KJ/SQ.M.
COLLECTED SOLAR ENERGY	64.772 GIGA JOULES
	265905 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	14 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.37
ECSS OPERATING ENERGY	1.381 GIGA JOULES
STORAGE EFFICIENCY	122.80 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	10.424 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	11.139 GIGA JOULES
TOTAL ENERGY CONSUMED	103.940 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	9.454	62.711	N.A.	72.164 GIGA JOULES
SOLAR FRACTION	33	79	N.A.	73 PERCENT
SOLAR ENERGY USED	3.159	49.669	N.A.	52.829 GIGA JOULES
OPERATING ENERGY	0.366	9.391	N.A.	11.139 GIGA JOULES
AUX. THERMAL ENG	6.294	13.042	N.A.	19.336 GIGA JOULES
AUX. ELECTRIC FUEL	6.294	N.A.	N.A.	6.294 GIGA JOULES
AUX. FOSSIL FUEL	N.A.	21.736	N.A.	21.736 GIGA JOULES
ELECTRICAL SAVINGS	2.793	-0.450	N.A.	0.962 GIGA JOULES
FOSSIL SAVINGS	N.A.	82.782	N.A.	82.782 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.90

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.02

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

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	2.047	44	0.021	N	0.068	0.000	0.010
2	4.316	51	0.909	O	0.068	0.000	0.211
3	3.480	54	1.055	T	0.053	0.000	0.303
4	5.553	53	1.539		0.029	0.000	0.277
5	2.910	51	1.674	A	0.030	0.000	0.575
6	4.465	51	1.813	P	0.038	0.000	0.406
7	3.873	50	1.510	P	0.036	0.000	0.390
8	5.133	55	1.925	L	0.034	0.000	0.375
9	3.401	59	1.637	I	0.049	0.000	0.481
10	0.801	59	0.001	C	0.068	0.000	0.001
11	2.053	58	0.339	A	0.067	0.000	0.165
12	3.231	57	0.868	B	0.067	0.000	0.268
13	1.974	57	0.434	L	0.067	0.000	0.220
14	2.512	57	0.643	E	0.067	0.000	0.256
15	5.706	54	1.807		0.055	0.000	0.317
16	5.851	55	2.279		0.039	0.000	0.390
17	5.715	56	2.027		0.032	0.000	0.355
18	5.781	60	1.300		0.027	0.000	0.225
19	5.664	63	2.612		0.032	0.000	0.461
20	5.642	69	2.803		0.041	0.000	0.497
21	5.442	69	2.169		0.034	0.000	0.398
22	5.660	67	2.561		0.034	0.000	0.453
23	5.577	64	2.846		0.042	0.000	0.510
24	5.556	60	2.072		0.032	0.000	0.373
25	4.844	59	1.350		0.025	0.000	0.279
26	5.310	58	2.591		0.033	0.000	0.488
27	5.586	58	2.765		0.042	0.000	0.495
28	5.446	59	2.074		0.034	0.000	0.381
29	5.400	63	2.142		0.035	0.000	0.397
30	5.247	57	2.308		0.034	0.000	0.440
SUM	134.178	-	50.074	N.A.	1.309	0.000	-
AVG	4.473	58	1.669	N.A.	0.044	0.000	0.373
PFRV	1.0000	1.0000	1.0000	N.A.	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	2.047	2.047	0.544	45	0.266	0.266
2	4.316	4.316	1.579	56	0.366	0.366
3	3.480	3.445	1.552	62	0.446	0.450
4	5.553	5.261	2.729	64	0.491	0.519
5	2.910	2.559	1.200	61	0.412	0.469
6	4.465	3.974	1.857	58	0.416	0.467
7	3.873	3.761	1.786	61	0.461	0.475
8	5.133	4.927	2.527	68	0.492	0.513
9	3.401	3.311	1.499	70	0.441	0.453
10	0.801	0.801	0.038	62	0.047	0.047
11	2.053	2.053	0.722	62	0.352	0.352
12	3.231	3.172	1.207	64	0.373	0.380
13	1.974	1.974	0.584	63	0.296	0.296
14	2.512	2.473	0.948	64	0.377	0.383
15	5.706	5.549	2.635	64	0.462	0.475
16	5.851	5.582	2.868	69	0.490	0.514
17	5.715	5.429	2.747	71	0.481	0.506
18	5.781	5.379	2.815	74	0.487	0.523
19	5.664	5.004	2.575	78	0.455	0.515
20	5.642	5.364	3.004	82	0.532	0.560
21	5.442	4.966	2.712	85	0.498	0.546
22	5.660	5.007	2.693	83	0.476	0.538
23	5.577	5.239	2.888	80	0.518	0.551
24	5.556	5.106	2.676	70	0.482	0.524
25	4.844	4.324	2.188	71	0.452	0.506
26	5.310	4.644	2.306	68	0.434	0.497
27	5.586	5.261	2.768	71	0.496	0.526
28	5.446	5.187	2.585	69	0.475	0.498
29	5.400	4.923	2.753	81	0.510	0.559
30	5.247	4.838	2.412	68	0.460	0.498
SUM	134.178	125.877	61.395	-	-	-
AVG	4.473	4.196	2.046	68	0.458	0.488
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

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	I	I	0.389	68	I
2			0.453	75	
3			0.263	81	
4			0.919	94	
5			-0.697	96	
6			-0.074	86	
7			0.016	88	
8			0.413	92	
9			-0.430	89	
10			-0.220	80	
11			0.108	79	
12			0.088	80	
13			-0.080	79	
14			0.053	79	
15			0.653	86	
16			0.417	95	
17			0.432	103	
18			1.115	115	
19			-0.280	125	
20			-0.311	111	
21			0.227	115	
22			0.131	117	
23			-0.306	109	
24			0.275	111	
25			0.466	117	
26			-0.587	118	
27			-0.398	102	
28			0.319	106	
29			0.265	109	
30			-0.161	109	
SUM	I	I	1.317	-	I
AVG			0.044	97	
PFRV			N.A.	1.0000	

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

HOT WATER SUBSYSTEM I

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER.	HOT WATER DEMAND MILLION BTU	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU
(NBS ID)		(N300)	(Q302)		(Q300)	(Q303)	(Q301)
1	0.099	4	0.070	5	0.004	0.012	0.095
2	0.109	11	0.073	9	0.012	0.012	0.097
3	0.044	5	0.009	10	0.002	0.012	0.042
4	0.017	0	0.000	0	0.000	0.012	0.017
5	0.431	32	0.407	33	0.136	0.012	0.294
6	0.399	25	0.371	27	0.099	0.012	0.301
7	0.394	25	0.362	28	0.100	0.012	0.294
8	0.368	28	0.338	27	0.102	0.012	0.266
9	0.019	2	0.001	25	0.000	0.012	0.019
10	0.017	4	0.002	15	0.001	0.012	0.017
11	0.020	2	0.002	8	0.000	0.012	0.019
12	0.414	24	0.387	25	0.098	0.012	0.316
13	0.388	21	0.358	23	0.081	0.012	0.307
14	0.383	16	0.354	19	0.063	0.012	0.320
15	0.414	22	0.377	23	0.089	0.012	0.324
16	0.460	31	0.429	31	0.141	0.012	0.319
17	0.066	22	0.030	28	0.014	0.012	0.051
18	0.048	28	0.020	25	0.013	0.011	0.034
19	0.545	53	0.525	53	0.290	0.011	0.255
20	0.507	42	0.486	45	0.214	0.012	0.292
21	0.453	46	0.422	48	0.209	0.012	0.244
22	0.506	46	0.480	48	0.232	0.011	0.274
23	0.490	40	0.463	43	0.196	0.012	0.294
24	0.039	32	0.019	29	0.013	0.010	0.027
25	0.019	10	0.003	26	0.002	0.009	0.017
26	0.533	46	0.513	47	0.247	0.010	0.286
27	0.446	34	0.420	35	0.151	0.010	0.295
28	0.450	34	0.410	36	0.155	0.012	0.295
29	0.459	37	0.434	38	0.168	0.011	0.291
30	0.425	38	0.397	40	0.163	0.010	0.263
SUM	8.961	-	8.164	-	2.995	0.347	5.966
AVG	0.299	33	0.272	36	0.100	0.012	0.199
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	0.095	N	-0.008	N	65	134	121	108	0.012
2	0.097	O	0.000	O	64	133	128	112	0.012
3	0.042	T	-0.010	T	69	131	18	13	0.012
4	0.017		-0.012		70	132	0	0	0.012
5	0.294	A	0.124	A	67	111	1117	1036	0.012
6	0.301	P	0.087	P	62	101	1159	1075	0.012
7	0.294	P	0.088	P	64	106	1031	958	0.012
8	0.266	L	0.090	L	64	113	826	764	0.012
9	0.019	I	-0.012	I	67	115	2	1	0.012
10	0.017	C	-0.012	C	66	118	4	3	0.012
11	0.019	A	-0.012	A	69	111	5	2	0.012
12	0.316	B	0.086	B	58	93	1341	1244	0.012
13	0.307	L	0.068	L	58	98	1058	983	0.012
14	0.320	E	0.050	E	64	92	1530	1402	0.012
15	0.324		0.077		64	100	1259	1161	0.012
16	0.319		0.129		66	107	1250	1165	0.012
17	0.051		0.002		70	136	56	50	0.012
18	0.034		0.002		72	135	38	34	0.011
19	0.255		0.279		68	122	1184	1102	0.011
20	0.292		0.203		65	110	1313	1218	0.012
21	0.244		0.197		65	117	967	898	0.012
22	0.274		0.221		69	117	1192	1110	0.011
23	0.294		0.184		68	106	1444	1336	0.012
24	0.027		0.002		71	129	40	34	0.010
25	0.017		-0.007		74	122	7	5	0.009
26	0.286		0.237		69	113	1402	1307	0.010
27	0.295		0.141		70	100	1682	1550	0.010
28	0.295		0.143		70	109	1243	1158	0.012
29	0.291		0.157		69	112	1207	1121	0.011
30	0.263		0.153		70	118	994	921	0.010
SUM	5.966	N.A.	2.648	N.A.	-	-	23616	21873	0.347
AVG	0.199	N.A.	0.088	N.A.	66	107	787	729	0.012
PFRV	1.0000	N.A.	1.0000	N.A.	1.0000	1.0000	1.0000	1.0000	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

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	1.872	1.872	0.018	1.854	1	-0.001	0.029	N	44
2	2.363	2.363	0.897	1.466	38	-0.009	1.495	O	51
3	1.592	1.592	1.053	0.540	66	-0.012	1.754	T	54
4	1.576	1.576	1.539	0.036	98	-0.011	2.565		53
5	2.104	2.104	1.538	0.566	73	-0.018	2.563	A	51
6	2.861	2.861	1.714	1.147	60	-0.024	2.857	P	51
7	2.097	2.097	1.410	0.686	67	-0.018	2.350	P	50
8	2.154	2.154	1.824	0.331	85	-0.017	3.039	L	55
9	2.082	2.082	1.637	0.445	79	-0.019	2.728	I	59
10	0.820	0.820	0.000	0.820	0	0.000	0.000	C	59
11	0.715	0.715	0.339	0.376	47	-0.005	0.565	A	58
12	1.347	1.347	0.770	0.578	57	-0.012	1.283	B	57
13	1.546	1.546	0.353	1.193	23	-0.008	0.589	L	57
14	1.284	1.284	0.580	0.704	45	-0.010	0.967	E	57
15	2.306	2.306	1.718	0.589	74	-0.017	2.863		54
16	2.578	2.578	2.138	0.440	83	-0.021	3.563		55
17	2.160	2.160	2.013	0.147	93	-0.015	3.355		56
18	1.287	1.287	1.286	0.001	100	-0.007	2.144		60
19	2.335	2.335	2.322	0.013	99	-0.015	3.870		63
20	2.591	2.591	2.589	0.002	100	-0.022	4.315		69
21	1.968	1.968	1.960	0.008	100	-0.015	3.266		69
22	2.339	2.339	2.329	0.010	100	-0.015	3.882		67
23	2.657	2.657	2.650	0.007	100	-0.023	4.417		64
24	2.067	2.067	2.060	0.007	100	-0.015	3.433		60
25	1.350	1.350	1.348	0.002	100	-0.008	2.247		59
26	2.352	2.352	2.343	0.008	100	-0.017	3.906		58
27	2.806	2.806	2.615	0.191	93	-0.025	4.358		58
28	2.087	2.087	1.919	0.168	92	-0.015	3.198		59
29	1.991	1.991	1.973	0.017	99	-0.016	3.289		63
30	2.155	2.155	2.146	0.010	100	-0.017	3.576		57
SUM	59.441	59.441	47.080	12.362	-	-0.426	78.466	-	-
AVG	1.981	1.981	1.569	0.412	79	-0.014	2.616	N.A.	58
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	N.A.	1.0000

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MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

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	1.872	0.018	0.000	0.282	0.001	N	3.090	16
2	2.363	0.897	0.000	0.334	0.009	O	2.444	15
3	1.592	1.053	0.000	0.274	0.012	T	0.900	6
4	1.576	1.539	0.000	0.166	0.011		0.061	8
5	2.104	1.538	0.000	0.317	0.018	A	0.944	10
6	2.861	1.714	0.000	0.408	0.024	P	1.911	12
7	2.097	1.410	0.000	0.301	0.018	P	1.144	11
8	2.154	1.824	0.000	0.315	0.017	L	0.551	8
9	2.082	1.637	0.000	0.346	0.019	I	0.742	6
10	0.820	0.000	0.000	0.266	0.000	C	1.366	5
11	0.715	0.339	0.000	0.171	0.005	A	0.627	6
12	1.347	0.770	0.000	0.298	0.012	B	0.963	5
13	1.546	0.353	0.000	0.382	0.008	L	1.988	9
14	1.284	0.580	0.000	0.296	0.010	E	1.173	7
15	2.306	1.718	0.000	0.315	0.017		0.981	8
16	2.578	2.138	0.000	0.358	0.021		0.734	8
17	2.160	2.013	0.000	0.273	0.015		0.245	8
18	1.287	1.286	0.000	0.159	0.007		0.001	4
19	2.335	2.322	0.000	0.292	0.015		0.022	2
20	2.591	2.589	0.000	0.383	0.022		0.003	0
21	1.968	1.960	0.000	0.287	0.015		0.013	0
22	2.339	2.329	0.000	0.292	0.015		0.017	0
23	2.657	2.650	0.000	0.387	0.023		0.012	0
24	2.067	2.060	0.000	0.256	0.015		0.012	4
25	1.350	1.348	0.000	0.158	0.008		0.003	2
26	2.352	2.343	0.000	0.310	0.017		0.014	4
27	2.806	2.615	0.000	0.409	0.025		0.318	6
28	2.087	1.919	0.000	0.287	0.015		0.280	4
29	1.991	1.973	0.000	0.293	0.016		0.029	0
30	2.155	2.146	0.000	0.285	0.017		0.016	5
SUM	59.441	47.080	0.000	8.901	0.426	N.A.	20.603	178
AVG	1.981	1.569	0.000	0.297	0.014	N.A.	0.687	6
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	N.A.	1.0000	N.A.

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - LIQUID SYSTEM P2736R APRIL 1982

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	781	N	44	45	N	I	I
2	1646	O	51	56	O		
3	1327	T	54	62	T		
4	2118		53	64			
5	1110	A	51	61	A		
6	1703	P	51	58	P		
7	1477	P	50	61	P		
8	1958	L	55	68	L		
9	1297	I	59	70	I		
10	305	C	59	62	C		
11	783	A	58	62	A		
12	1232	B	57	64	B		
13	753	L	57	63	L		
14	958	E	57	64	E		
15	2176		54	64			
16	2231		55	69			
17	2180		56	71			
18	2205		60	74			
19	2160		63	78			
20	2152		69	82			
21	2076		69	85			
22	2159		67	83			
23	2127		64	80			
24	2119		60	70			
25	1848		59	71			
26	2025		58	68			
27	2130		58	71			
28	2077		59	69			
29	2060		63	81			
30	2001		57	68			
SUM	51174	N.A.	-	-	-		
AVG	1706	N.A.	58	68	N.A.	I	I
PFRV	1.0000	N.A.	1.0000	1.0000	N.A.		

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

MONTHLY REPORT: APRIL 1982
SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM P2736R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	39.041 MILLION BTU
	23308 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	0.000 MILLION BTU
	0 BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	0 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.000
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	0.000
AVERAGE AMBIENT TEMPERATURE	60 DEGREES F
AVERAGE BUILDING TEMPERATURE	74 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.00
ECSS OPERATING ENERGY	0.000 MILLION BTU
ECSS PERFORMANCE FACTOR	0 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	0.000 MILLION BTU
TOTAL ENERGY CONSUMED	0.000 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	0 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	0 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	N.A.	0.000 MILLION BTU
SOLAR FRACTION	N.A.	0	N.A.	0 PERCENT
SOLAR SAVINGS RATIO	N.A.	0.000	N.A.	0.000
SOLAR ENERGY USED	N.A.	0.000	N.A.	0.000 MILLION BTU
OPERATING ENERGY	N.A.	0.000	N.A.	0.000 MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.000	N.A.	0.000 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	0.000	N.A.	0.000 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 MILLION BTU
FOSSIL SAVINGS	N.A.	0.000	N.A.	0.000 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.03

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

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

MONTHLY REPORT: APRIL 1982
SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM P2736R

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	39.041 MILLION BTU
	23308 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	0.000 MILLION BTU
	0 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	60 DEGREES F
AVERAGE BUILDING TEMPERATURE	74 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.00
ECSS OPERATING ENERGY	0.000 MILLION BTU
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	0.000 MILLION BTU
TOTAL ENERGY CONSUMED	0.000 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	N.A.	0.000 MILLION BTU
SOLAR FRACTION	N.A.	0	N.A.	0 PERCENT
SOLAR ENERGY USED	N.A.	0.000	N.A.	0.000 MILLION BTU
OPERATING ENERGY	N.A.	0.000	N.A.	0.000 MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.000	N.A.	0.000 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	0.000	N.A.	0.000 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 MILLION BTU
FOSSIL SAVINGS	N.A.	0.000	N.A.	0.000 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 100.00
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.03

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

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

MONTHLY REPORT: APRIL 1982
SITE SUMMARY: OAKMEAD INDUSTRIES - AIR SYSTEM P2736R

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	41.188 GIGA JOULES
	264687 KJ/SQ.M.
COLLECTED SOLAR ENERGY	0.000 GIGA JOULES
	0 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	15 DEGREES C
AVERAGE BUILDING TEMPERATURE	23 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.00
ECSS OPERATING ENERGY	0.000 GIGA JOULES
STORAGE EFFICIENCY	N.A. PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	0.000 GIGA JOULES
TOTAL ENERGY CONSUMED	0.000 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.000	N.A.	0.000 GIGA JOULES
SOLAR FRACTION	N.A.	0	N.A.	0 PERCENT
SOLAR ENERGY USED	N.A.	0.000	N.A.	0.000 GIGA JOULES
OPERATING ENERGY	N.A.	0.000	N.A.	0.000 GIGA JOULES
AUX. THERMAL ENG	N.A.	0.000	N.A.	0.000 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	N.A.	0.000	N.A.	0.000 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	0.000 GIGA JOULES
FOSSIL SAVINGS	N.A.	0.000	N.A.	0.000 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 100.00
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.03

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

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM P2736R APRIL 1982
ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	0.710	46	0.000	N	0.000	N	0.000
2	1.516	51	0.000	O	0.000	O	0.000
3	1.221	56	0.000	T	0.000	T	0.000
4	1.795	55	0.000		0.000		0.000
5	1.023	53	0.000	A	0.000	A	0.000
6	1.451	53	0.000	P	0.000	P	0.000
7	1.300	52	0.000	P	0.000	P	0.000
8	1.653	57	0.000	L	0.000	L	0.000
9	1.170	60	0.000	I	0.000	I	0.000
10	0.239	61	0.000	C	0.000	C	0.000
11	0.736	59	0.000	A	0.000	A	0.000
12	1.055	57	0.000	B	0.000	B	0.000
13	0.665	57	0.000	L	0.000	L	0.000
14	0.814	58	0.000	E	0.000	E	0.000
15	1.575	56	0.000		0.000		0.000
16	1.630	57	0.000		0.000		0.000
17	1.581	58	0.000		0.000		0.000
18	1.592	62	0.000		0.000		0.000
19	1.560	66	0.000		0.000		0.000
20	1.499	70	0.000		0.000		0.000
21	1.731	70	0.000		0.000		0.000
22	1.764	69	0.000		0.000		0.000
23	1.467	66	0.000		0.000		0.000
24	1.417	63	0.000		0.000		0.000
25	1.313	61	0.000		0.000		0.000
26	1.355	61	0.000		0.000		0.000
27	1.319	61	0.000		0.000		0.000
28	1.280	62	0.000		0.000		0.000
29	1.304	66	0.000		0.000		0.000
30	1.305	60	0.000		0.000		0.000
SUM	39.041	-	0.000	N.A.	0.000	N.A.	-
AVG	1.301	60	0.000	N.A.	0.000	N.A.	0.000
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 P2736R APRIL 1982

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	0.710	0.000	0.000	47	0.000	0.000
2	1.516	0.000	0.000	54	0.000	0.000
3	1.221	0.000	0.000	61	0.000	0.000
4	1.795	0.000	0.000	63	0.000	0.000
5	1.023	0.000	0.000	58	0.000	0.000
6	1.451	0.000	0.000	58	0.000	0.000
7	1.300	0.000	0.000	59	0.000	0.000
8	1.653	0.000	0.000	65	0.000	0.000
9	1.170	0.000	0.000	67	0.000	0.000
10	0.239	0.000	0.000	63	0.000	0.000
11	0.736	0.000	0.000	61	0.000	0.000
12	1.055	0.000	0.000	62	0.000	0.000
13	0.665	0.000	0.000	62	0.000	0.000
14	0.814	0.000	0.000	64	0.000	0.000
15	1.575	0.000	0.000	62	0.000	0.000
16	1.630	0.000	0.000	68	0.000	0.000
17	1.581	0.000	0.000	69	0.000	0.000
18	1.592	0.000	0.000	72	0.000	0.000
19	1.560	0.000	0.000	76	0.000	0.000
20	1.499	0.000	0.000	79	0.000	0.000
21	1.731	0.000	0.000	81	0.000	0.000
22	1.764	0.000	0.000	82	0.000	0.000
23	1.467	0.000	0.000	77	0.000	0.000
24	1.417	0.000	0.000	70	0.000	0.000
25	1.313	0.000	0.000	70	0.000	0.000
26	1.355	0.000	0.000	69	0.000	0.000
27	1.319	0.000	0.000	69	0.000	0.000
28	1.280	0.000	0.000	69	0.000	0.000
29	1.304	0.000	0.000	79	0.000	0.000
30	1.305	0.000	0.000	68	0.000	0.000
SUM	39.041	0.000	0.000	-	-	-
AVG	1.301	0.000	0.000	67	0.000	0.000
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 P2736R APRIL 1982

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	0.000	0.000	0.000	0.000	0	N	0.000	70	46
2	0.000	0.000	0.000	0.000	0	O	0.000	71	51
3	0.000	0.000	0.000	0.000	0	T	0.000	71	56
4	0.000	0.000	0.000	0.000	0		0.000	71	55
5	0.000	0.000	0.000	0.000	0	A	0.000	71	53
6	0.000	0.000	0.000	0.000	0	P	0.000	72	53
7	0.000	0.000	0.000	0.000	0	P	0.000	72	52
8	0.000	0.000	0.000	0.000	0	L	0.000	72	57
9	0.000	0.000	0.000	0.000	0	I	0.000	73	60
10	0.000	0.000	0.000	0.000	0	C	0.000	72	61
11	0.000	0.000	0.000	0.000	0	A	0.000	71	59
12	0.000	0.000	0.000	0.000	0	B	0.000	72	57
13	0.000	0.000	0.000	0.000	0	L	0.000	72	57
14	0.000	0.000	0.000	0.000	0	E	0.000	73	58
15	0.000	0.000	0.000	0.000	0		0.000	73	56
16	0.000	0.000	0.000	0.000	0		0.000	75	57
17	0.000	0.000	0.000	0.000	0		0.000	74	58
18	0.000	0.000	0.000	0.000	0		0.000	74	62
19	0.000	0.000	0.000	0.000	0		0.000	76	66
20	0.000	0.000	0.000	0.000	0		0.000	77	70
21	0.000	0.000	0.000	0.000	0		0.000	79	70
22	0.000	0.000	0.000	0.000	0		0.000	78	69
23	0.000	0.000	0.000	0.000	0		0.000	77	66
24	0.000	0.000	0.000	0.000	0		0.000	76	63
25	0.000	0.000	0.000	0.000	0		0.000	74	61
26	0.000	0.000	0.000	0.000	0		0.000	75	61
27	0.000	0.000	0.000	0.000	0		0.000	76	61
28	0.000	0.000	0.000	0.000	0		0.000	76	62
29	0.000	0.000	0.000	0.000	0		0.000	77	66
30	0.000	0.000	0.000	0.000	0		0.000	76	60
SUM	0.000	0.000	0.000	0.000	-	N.A.	0.000	-	-
AVG	0.000	0.000	0.000	0.000	0	N.A.	0.000	74	60
PFRV	1.0000	1.0000	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 - AIR SYSTEM P2736R APRIL 1982

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	0.000	0.000	0.000	0.000	0.000	N	0.000	18
2	0.000	0.000	0.000	0.000	0.000	O	0.000	15
3	0.000	0.000	0.000	0.000	0.000	T	0.000	8
4	0.000	0.000	0.000	0.000	0.000		0.000	8
5	0.000	0.000	0.000	0.000	0.000	A	0.000	10
6	0.000	0.000	0.000	0.000	0.000	P	0.000	11
7	0.000	0.000	0.000	0.000	0.000	P	0.000	12
8	0.000	0.000	0.000	0.000	0.000	L	0.000	7
9	0.000	0.000	0.000	0.000	0.000	I	0.000	6
10	0.000	0.000	0.000	0.000	0.000	C	0.000	4
11	0.000	0.000	0.000	0.000	0.000	A	0.000	7
12	0.000	0.000	0.000	0.000	0.000	B	0.000	7
13	0.000	0.000	0.000	0.000	0.000	L	0.000	9
14	0.000	0.000	0.000	0.000	0.000	E	0.000	6
15	0.000	0.000	0.000	0.000	0.000		0.000	7
16	0.000	0.000	0.000	0.000	0.000		0.000	8
17	0.000	0.000	0.000	0.000	0.000		0.000	6
18	0.000	0.000	0.000	0.000	0.000		0.000	1
19	0.000	0.000	0.000	0.000	0.000		0.000	1
20	0.000	0.000	0.000	0.000	0.000		0.000	0
21	0.000	0.000	0.000	0.000	0.000		0.000	0
22	0.000	0.000	0.000	0.000	0.000		0.000	0
23	0.000	0.000	0.000	0.000	0.000		0.000	0
24	0.000	0.000	0.000	0.000	0.000		0.000	1
25	0.000	0.000	0.000	0.000	0.000		0.000	1
26	0.000	0.000	0.000	0.000	0.000		0.000	2
27	0.000	0.000	0.000	0.000	0.000		0.000	3
28	0.000	0.000	0.000	0.000	0.000		0.000	2
29	0.000	0.000	0.000	0.000	0.000		0.000	0
30	0.000	0.000	0.000	0.000	0.000		0.000	2
SUM	0.000	0.000	0.000	0.000	0.000	N.A.	0.000	162
AVG	0.000	0.000	0.000	0.000	0.000	N.A.	0.000	5
PFRV	1.0000	1.0000	1.0000	1.0000	1.0000	N.A.	1.0000	N.A.

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

MONTHLY REPORT: OAKMEAD INDUSTRIES - AIR SYSTEM P2736R APRIL 1982
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	424	N	46	47	N	I	I
2	905	O	51	54	O		
3	729	T	56	61	T		
4	1072		55	63			
5	611	A	53	58	A		
6	866	P	53	58	P		
7	776	P	52	59	P		
8	987	L	57	65	L		
9	699	I	60	67	I		
10	143	C	61	63	C		
11	439	A	59	61	A		
12	630	B	57	62	B		
13	397	L	57	62	L		
14	486	E	58	64	E		
15	940		56	62			
16	973		57	68			
17	944		58	69			
18	950		62	72			
19	931		66	76			
20	895		70	79			
21	1034		70	81			
22	1053		69	82			
23	876		66	77			
24	846		63	70			
25	784		61	70			
26	809		61	69			
27	788		61	69			
28	764		62	69			
29	778		66	79			
30	779		60	68			
SUM	23308	N.A.	-	-	-		
AVG	777	N.A.	60	67	N.A.	I	I
PFRV	1.0000	N.A.	1.0000	1.0000	N.A.		

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

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-646-069/184