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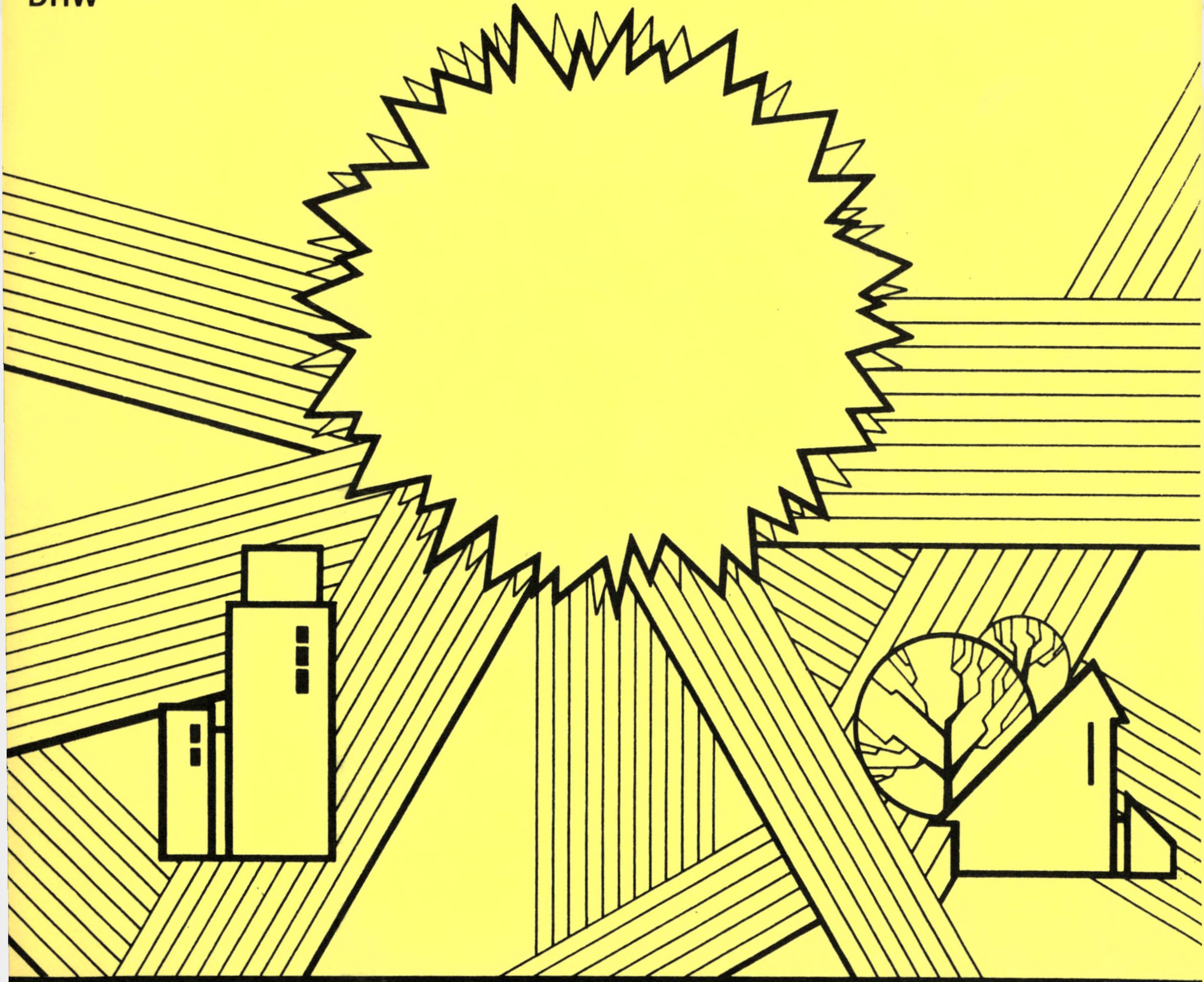
SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

CRAFTSMAN ENTERPRISES
Dallas, Texas
September 1981 through March 1982
DHW



U.S. DEPARTMENT OF ENERGY
NATIONAL SOLAR DATA PROGRAM

SOLAR/2123-82/14
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CRAFTSMAN ENTERPRISES

DALLAS, TEXAS

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

SEPTEMBER 1981 THROUGH MARCH 1982

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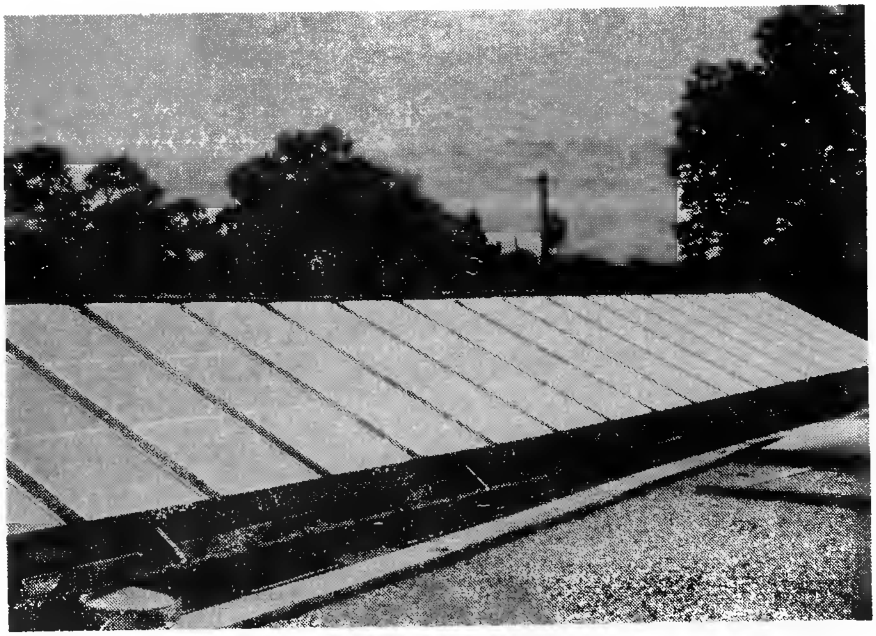
FOREWORD

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.



CRAFTSMAN ENTERPRISES

CRAFTSMAN ENTERPRISES

Craftsman Enterprises is an industrial laundry in Dallas, Texas. The active solar energy system is equipped with:

Collector: 1,011 square feet of liquid collector panels, manufactured by S-Systems Collectors.

Storage: 2,000-gallon steel tank (eight-foot diameter, six-foot radius) located outside.

Auxiliary: Two 100-gallon gas-fired hot water heaters in series with a condensate heat exchanger which is piped to a steam boiler.

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SECTION 1

SOLAR SYSTEM PERFORMANCE

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

Solar Fraction[1]	14%
Solar Savings Ratio[2]	0.12
Conventional Fuel Savings[3]	63,916 cubic feet of natural gas
Operating Energy Expenditure[4]	1,776 kwh
System Performance Factor[5]	0.68
Solar System COP[6]	6.46

Energy Requirements
September 1981 through March 1982
(Million BTU)

	Total Load	Secondary Load	Solar Contribution	Reclaimed Energy	Solar Fraction of Secondary Load (%)	Reclaimed Fraction of Total Load (%)
Hot Water	291.05	270.20	39.16	20.85	14	7

Environmental Data

	Measured Average	Long-Term Average
Outdoor temperature	58°F	57°F
Heating degree-days (Total)	2,176	2,219
Cooling degree-days (Total)	687	584
Daily incident solar energy	1,221 BTU/ft^2	1,419 BTU/ft^2

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

2. Solar Savings Ratio $= \dfrac{\text{Solar Energy Supplied to Load - Solar System Operating Energy}}{\text{Secondary Load}}$

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

4. Operating Energy Expenditure = Operating energy in BTU x 292.8 x 10^{-6} kwh/BTU

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

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

1.1 SUMMARY AND CONCLUSIONS

The Craftsman Enterprises solar energy system performed poorly during the September 1981 through March 1982 reporting period. The solar system supplied 14% of the new energy (270.20 million BTU) delivered to the hot water subsystem. The heat reclamation system supplied seven percent of the total system load of 291.05 million BTU. In this case, the total system load is defined as the total energy supplied to the hot water subsystem control volume, including recycled energy, solar energy delivered to storage, and auxiliary thermal energy added by the two gas-fired hot water tanks and the condensate heat exchanger. Since the recycled energy has already been tallied as either solar or auxiliary thermal energy, a secondary hot water load has been defined as the new energy added to the control volume and thus excludes the recycled energy (refer to Appendix D).

The overall performance of the solar energy system is presented in Table 1 and shown graphically in Figure 1. The solar system provided a fossil fuel savings of 63,916 cubic feet of natural gas at an electric operating expense of 1,776 kwh. The recycled energy saved an additional 34,034 cubic feet of natural gas for a total conservation system savings of 97,950 cubic feet.

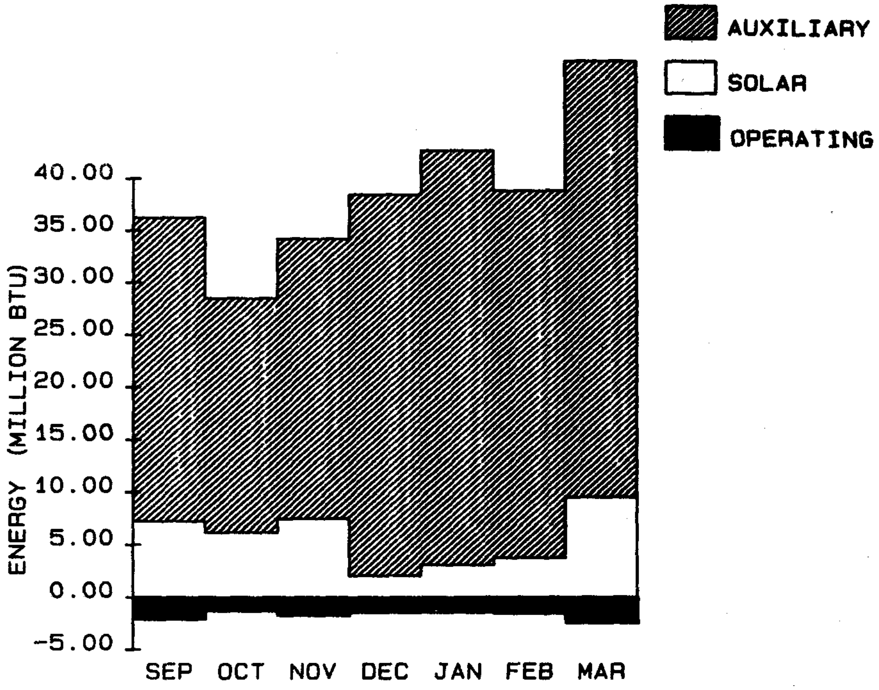
Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

			NONPURCHASED ENERGY USED		AUXILIARY ENERGY			ENERGY SAVINGS			SOLAR FRACTION (%)	
MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	RECLAIMED	SOLAR	THERMAL	FOSSIL	OPERATING ENERGY	FOSSIL DUE TO RECLAIM	FOSSIL DUE TO SOLAR	ELECTRICAL	PERCENTAGE OF TOTAL LOAD BY RECLAIMED	MEASURED* SOLAR
SEP	7.22	37.54	1.34	7.22	28.98	48.30	2.13	2.23	12.03	-1.62	4	20
OCT	6.14	30.21	1.76	6.14	22.31	37.18	1.34	2.93	10.23	-0.82	6	22
NOV	7.46	36.34	2.17	7.46	26.71	44.52	1.74	3.62	12.43	-0.88	6	22
DEC	2.05	41.49	3.06	2.05	36.38	60.63	1.46	5.10	3.42	-0.47	7	5
JAN	3.07	46.72	4.01	3.07	39.64	66.07	1.46	6.68	5.12	-0.41	9	7
FEB	3.75	42.56	3.74	3.75	35.07	58.45	1.55	6.23	6.25	-0.57	9	10
MAR	9.47	56.19	4.77	9.47	41.95	69.92	2.45	7.95	15.78	-1.29	8	18
TOTAL	39.16	291.05	20.85	39.16	231.04	385.07	12.13	34.74	65.26	-6.06	-	-
AVERAGE	5.59	41.58	2.98	5.59	33.01	55.01	1.73	4.96	9.32	-0.87	7	14

* Solar fraction based on percentage of new energy used (secondary hot water load) supplied by solar (see Table 5).



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

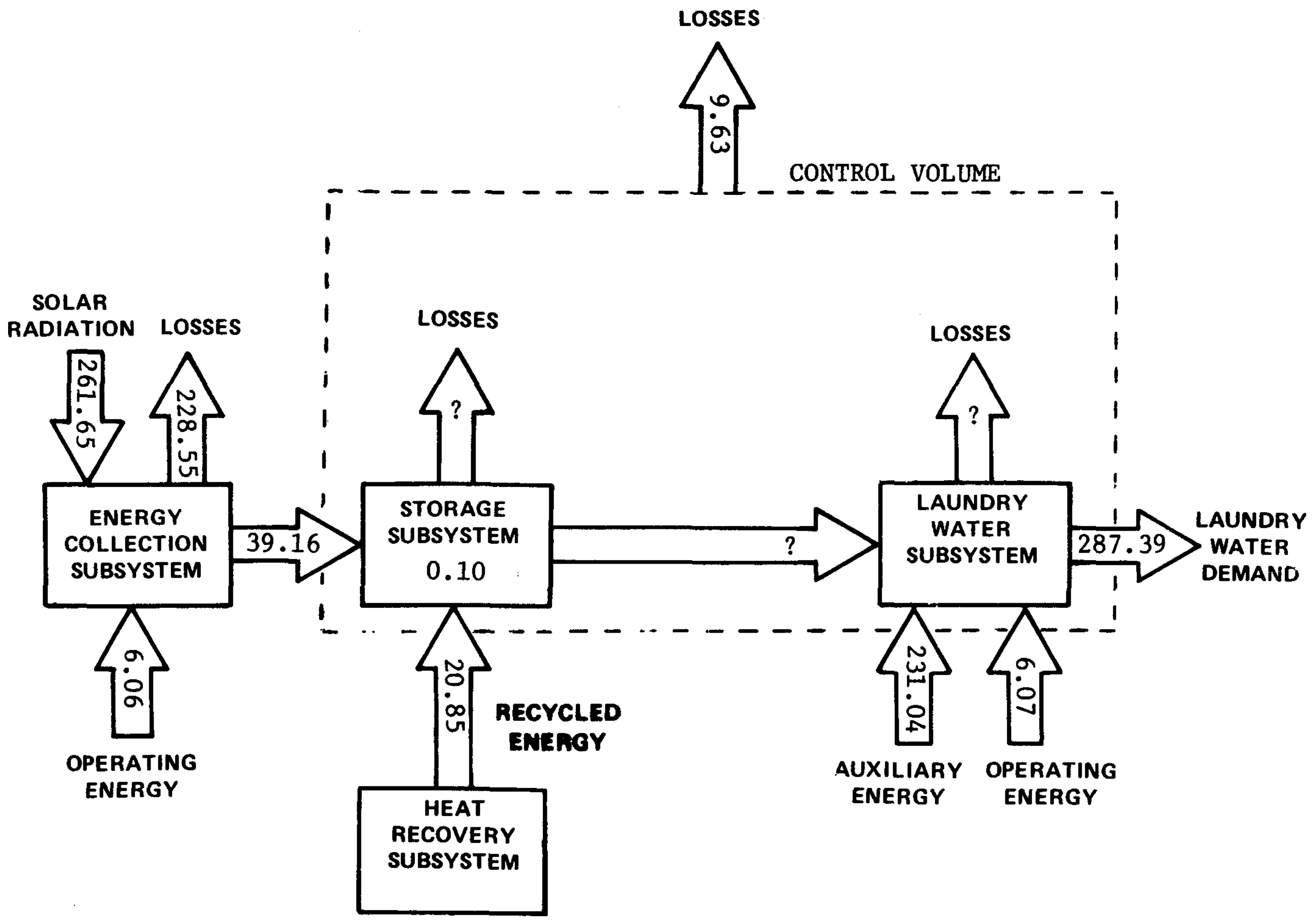
Figure 1. System Thermal Performance
Craftsman Enterprises
September 1981 through March 1982

This system performed poorly due to nonoptimal control of the collector control pump. The controller failed during late summer and was operated manually throughout the entire reporting period. The manual operation resulted in several system penalties, notably no collector pump operation on Sundays, holidays, and extended periods during December 1981 and January 1982. At other times, system operators forgot to turn the pump off and it ran continuously. This resulted in rejection of collected energy and increased operating energy expenses.

In other instances, the collector pump was turned on at least an hour before sunrise, again rejecting energy and driving up operating costs.

The gross solar energy collected was 55.25 million BTU, while the net collected energy was 39.16 million BTU. Thus only 71% of the gross collected energy was eventually delivered to the load subsystem. The high operating expenditures resulted in a collector subsystem Coefficient of Performance (COP) (defined as solar energy collected divided by the operating energy used to collect it) of 6.46. Table 2 presents total solar system and collection subsystem COP for each month. A second reason for the low COPs at this site is that it uses a draindown configuration which requires larger less efficient pumps. It is highly unlikely that this collector subsystem COP could result in real monetary savings at this site with natural gas as the auxiliary fuel source.

Referring to Figure 2, the Energy Flow Diagram, it is uncertain how much of the losses occurred out of storage because of a failed temperature sensor



? DENOTES UNKNOWN VALUE

Figure 2. Energy Flow Diagram for Craftsman Enterprises
September 1981 through March 1982
(Figures in million BTU)

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM
SEP	4.46	4.46
OCT	7.49	7.49
NOV	8.48	8.48
DEC	4.36	4.36
JAN	7.49	7.49
FEB	6.58	6.58
MAR	7.34	7.34
WEIGHTED AVERAGE	6.46	6.46

(T301), but it is expected that the bulk of the combined losses were lost out of storage because the storage tank is located outside and has only one inch of polyurethane insulation on most of the tank and no insulation on about 18 square feet of the tank surface.

The Craftsman Enterprises collector array consists of 43 S-system collector flat-plate panels in two rows. There are 22 panels in the front row and 21 panels in the rear. The rows are plumbed in parallel with a central feed line. Each panel measures 96.75 inch x 35 inch gross or 94.75 inch x 33 inch aperture area for a gross collector area of 1,011 square feet. The collectors are tilted at 27 degrees from the horizontal and face one degree west of solar south.

During collector flow, a constant 18.5 gallons per minute (gpm) (0.018 gpm per square foot of collector) were observed. This is very near the "rule of thumb" design value of 0.022 gpm per square foot for flat-plate liquid systems.

Collector subsystem performance is presented in Table 3. The ratio of operational incident solar energy (energy incident during collector flow) to the total incident solar energy was 60%. This ratio was lowest in December 1981 (27%) and January 1982 (29%) because of periods during both months when the collector pump was not activated. The pump was not turned on for many days in December and from January 21 through January 25. These off-times are in addition to not being turned on on Sundays and holidays. The factor in Table 3 denoted "Energy to Storage" is defined as the sum of the collected solar energy and the recovered waste energy delivered to storage (SUMP) (refer to the site equations, Appendix D).

Table 3. COLLECTOR SUBSYSTEM PERFORMANCE

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 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 OPERATING ENERGY	ENERGY TO STORAGE	DAYTIME AMBIENT TEMPERATURE (°F)
SEP	50.95	7.22	14	33.46	22	1.62	8.56	84
OCT	33.81	6.14	18	26.20	23	0.82	7.90	71
NOV	39.64	7.46	19	29.33	25	0.88	9.63	65
DEC	32.66	2.05	6	8.97	23	0.47	5.11	53
JAN	36.55	3.07	8	10.64	29	0.41	7.08	52
FEB	30.20	3.75	12	15.01	25	0.57	7.49	50
MAR	37.84	9.47	25	32.09	30	1.29	14.24	65
TOTAL	261.65	39.16	-	155.70	-	6.06	60.01	-
AVERAGE	37.38	5.59	15	22.24	25	0.87	8.57	63

The table below shows the total hours of collector pump operation, the collector operating energy, and number of hours when the incident solar energy was greater than zero.

MONTH	NUMBER OF COLLECTOR PUMP HOURS	COLLECTOR OPERATING ENERGY (MILLION BTU)	NUMBER OF HOURS OF SUNSHINE
SEP	370	1.62	368
OCT	187	0.82	313
NOV	199	0.88	326
DEC	115	0.47	314
JAN	98	0.41	316
FEB	136	0.57	296
MAR	300	1.29	353
TOTAL	1,405	6.06	2,286
AVERAGE	201	0.87	327

Excessive hours of pump operation occurred in September because the pump was left on continuously for the first eight days. Also, during September the collector remained on throughout the nights of September 13 and 17, from September 19 through the afternoon of September 23, and from September 26 through September 28. The pump was not turned on at all on September 25.

Other times when the collector pump was not controlled in a satisfactory manner occurred in October when the pump was not activated on October 4, 18, or 25, and left running all night on October 27. The pump was not left on all night again for the remainder of the season but was not activated on the following days:

November 1, 8, 15, 26, 28, 29
December 6, 10, 11, 20, 25, 26, 27
January 1, 9, 10, 14, 16, 17, 21-27, 31
February 6-8, 12-15, 20, 21, 27
March 5, 6, 28

Figure 3 presents a plot of the collector array efficiency versus operating point for the seven reporting months along with mean and weighted average composite curves. The operating point is defined as the temperature difference between the collector inlet temperature and the ambient temperature, divided by the insolation per square foot of collector. The weighted average was weighted by the number of points. The data was plotted from data contained in the table below.

MONTH	SLOPE	Y-INTERCEPT	CORRELATION COEFFICIENT	STANDARD DEVIATION	NUMBER OF POINTS
SEP	-0.890	0.471	0.679	0.014	96
OCT	-0.980	0.532	0.933	0.035	89
NOV	-1.281	0.532	0.935	0.035	102
DEC	-1.130	0.467	0.790	0.052	33
JAN	-1.427	0.439	0.624	0.013	22
FEB	-1.383	0.539	0.897	0.042	40
MAR	-1.132	0.501	0.886	0.055	140
TOTAL	-	-	-	-	530
MEAN	-1.175	0.497	0.821	0.035	76
WEIGHTED AVERAGE	-1.122	0.505	0.850	0.037	-

The y-intercept and the slope are the well known $FR(\tau\alpha)$ and F_RU_L factors in the Hottel-Whillier-Bliss equations. The plot shows a fairly high heat loss coefficient (weighted average $F_RU_L = -1.122$) for these collectors which have a copper roll bond absorber painted black and covered with plastic glazing reinforced with fiberglass.

The September and October curves have flatter slopes which may be related to a leakage problem in the collector loop during those months.

Table 4 presents storage performance. Due to an early failure of temperature sensor T301, values are not available for energy withdrawn from storage. Hence, storage losses, efficiency, and effective heat loss are not available from an energy balance viewpoint. However, since the system remains stagnant (i.e. no solar collector operation, no makeup flow through the system) on many days, energy decay curves were used to arrive at an approximate R value for storage. When there is an adequate (>20°F) temperature differential between

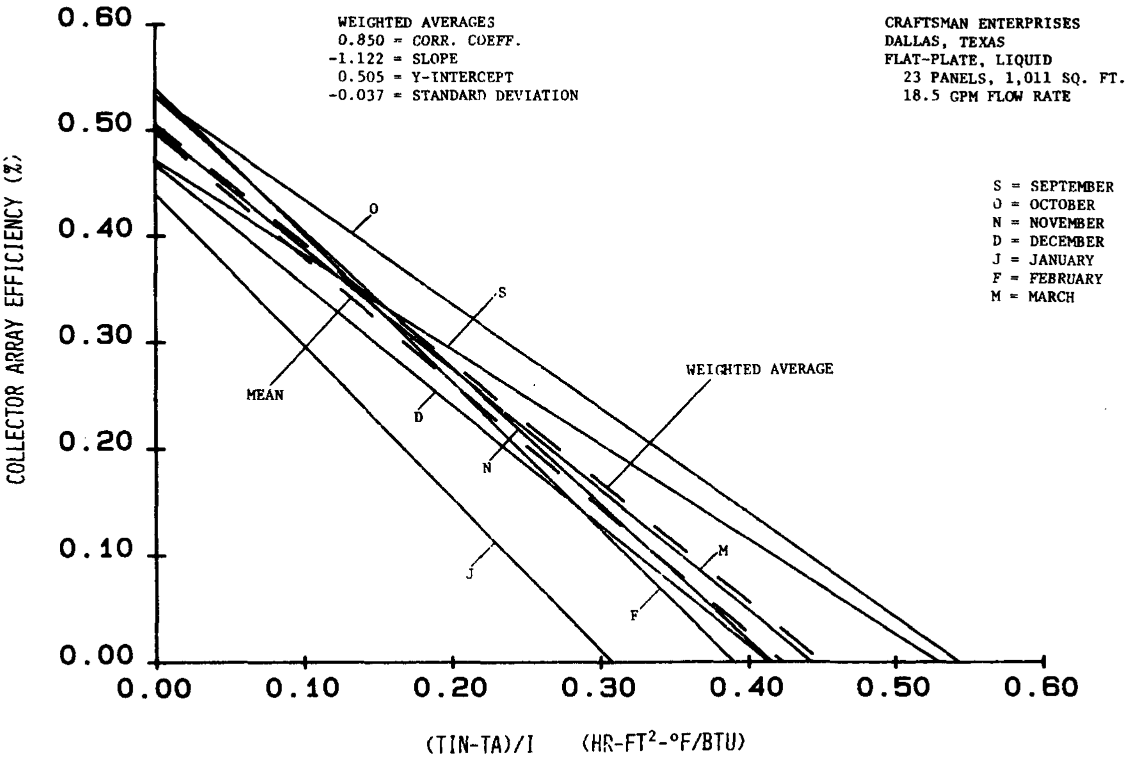


Figure 3. Average Collector Efficiency
Craftsman Enterprises
September 1981 through March 1982

Table 4. STORAGE PERFORMANCE

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	CHANGE IN STORED ENERGY	AVERAGE STORAGE TEMPERATURE (°F)
SEP	8.56	0.47	111
OCT	7.90	-0.68	101
NOV	9.63	0.10	95
DEC	5.11	-0.50	71
JAN	7.08	-0.07	61
FEB	7.49	-0.05	64
MAR	14.24	0.83	81
TOTAL	60.01	0.10	-
AVERAGE	8.57	0.01	83

storage and ambient in the vicinity of storage, the temperature in the tank should decay according to:

$$\frac{T(t)}{T(0)} = e^{-At/RCpM}$$

Where T(t) = Temperature at end of decay period in degrees Rankine

T(0) = Temperature at beginning of decay period in degrees Rankine

e = Base of natural (Napierian) logarithms

A = Area of the tank = 251.33 ft^2

t = Time of decay period in hours

R = R value of tank

Cp = Specific heat of water = 1 $BTU/lb_m{}^\circ F$

M = Mass of water in storage = 2,000 x 8.338 = 16,676 lb_m

The best curve fit resulted in an R value of 7.4 $ft^2{}^\circ F$-hr/BTU.

This seems to be high for an outside storage tank covered with one inch of polyurethane, especially since an 18-square-foot area has no insulation. The 7.4 R value can be used to estimate the losses from storage by the following equation.

$$STLOSS = [A \times (TST - TA)/R] \times hours$$

where: STLOSS = Storage loss

TST = Temperature of storage

TA = Ambient temperature in vicinity of storage

Using average values TST = 83°F and TA = 58°F, with 5,088 hours results in an energy loss from storage of approximately 4.32 million BTU and a storage efficiency of 93%.

Table 5 presents performance of the process hot water system. The total hot water load was 291.05 million BTU of which 20.85 million BTU were supplied by reclaimed energy, resulting in a secondary hot water load of 270.20 million BTU. The secondary hot water load is defined as the total new energy added to the system. A total of 314,882 gallons of water was heated from a makeup temperature of 59°F to 66°F by passing through the sump pit, and then heated to 167°F by the remainder of the system. This resulted in a total hot water demand of 287.39 million BTU and a secondary demand of 266.54 million BTU. The secondary hot water load was met by 39.16 million BTU of solar energy and 231.04 million BTU of auxiliary thermal energy, resulting in a solar fraction of 14%. The solar fraction is calculated based on the secondary load since the recycled energy had already been accounted for as either solar or auxiliary thermal energy.

Table 5. PROCESS HOT WATER SUBSYSTEM

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	TOTAL HOT WATER LOAD	SECONDARY HOT WATER LOAD	SOLAR FRACTION OF SECONDARY HOT WATER LOAD (%)	TOTAL HOT WATER DEMAND	SECONDARY HOT WATER DEMAND	SOLAR ENERGY USED	RECLAIMED ENERGY	AUX THERMAL FUEL	AUX FOSSIL FUEL	SUP WATER TEMP (°F)	SUMP PIT OUTLET TEMP (°F)	HOT WATER TEMP (°F)	HOT WATER CONSUMPTION (GALLONS)
SEP	37.54	36.20	20	37.34	36.00	7.22	1.34	28.98	48.30	80	85	196	37,492
OCT	30.21	28.45	22	29.63	27.87	6.14	1.76	22.31	37.18	73	79	170	34,621
NOV	36.34	34.17	22	35.15	32.98	7.46	2.17	26.71	44.52	64	71	175	35,186
DEC	41.49	38.43	5	41.75	38.69	2.05	3.06	36.38	60.63	57	65	167	45,611
JAN	46.72	42.71	7	46.28	42.27	3.07	4.01	39.64	66.07	49	58	156	51,855
FEB	42.56	38.82	10	42.74	39.00	3.75	3.74	35.07	58.45	46	56	160	45,064
MAR	56.19	51.42	18	54.50	49.73	9.47	4.77	41.95	69.92	56	65	160	65,053
TOTAL	291.05	270.20	-	287.39	266.54	39.16	20.85	231.04	385.07	-	-	-	314,882
AVERAGE	41.58	38.60	14	41.06	38.08	5.59	2.98	33.01	55.01	59	66	167	44,983

The auxiliary thermal energy was provided by two means, two gas-fired hot water tanks and a condensate heat exchanger. The following table indicates the contributions for each auxiliary component.

(All figures in million BTU)

MONTH	ENERGY ADDED AT TANKS	ENERGY ADDED AT CONDENSATE HEAT EXCHANGER	TOTAL AUXILIARY THERMAL ENERGY
SEP	3.09	25.89	29.98
OCT	12.73	9.58	22.31
NOV	17.60	9.11	26.71
DEC	25.87	10.51	36.38
JAN	28.67	10.97	39.64
FEB	25.82	9.25	35.07
MAR	29.21	12.74	41.95
TOTAL	142.99	88.05	231.04
AVERAGE	20.43	12.58	33.01

Table 6 presents the energy savings for both the solar system and the heat reclamation system. Solar-specific operating energy is considered a cost and is therefore reported as a negative in the electrical savings columns. Use of solar energy saved 65.26 million BTU (63,916 cubic feet of natural gas) of fossil energy with an electrical energy expenditure of 6.06 million BTU (1,776 kwh). Use of the heat reclamation system saved an additional 34.74 million BTU (34,034 cubic feet of natural gas). With assumed costs of $4.67 per thousand cubic feet and 6.48 cents per kwh, the monetary savings due to use of the solar system were $183 with an additional $159 saved by using the heat reclamation system.

Table 6. ENERGY SAVINGS

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	RECLAIMED ENERGY	DOMESTIC HOT WATER		ECSS OPERATING ENERGY SOLAR-UNIQUE	NET ENERGY SAVINGS	
			FOSSIL FUEL (SOLAR)	FOSSIL FUEL (RECLAIM)		ELECTRICAL	FOSSIL FUEL
SEP	7.22	1.34	12.03	2.23	1.62	-1.62	14.26
OCT	6.14	1.76	10.23	2.93	0.82	-0.82	13.16
NOV	7.46	2.17	12.43	3.62	0.88	-0.88	16.05
DEC	2.05	3.06	3.42	5.10	0.47	-0.47	8.52
JAN	3.07	4.01	5.12	6.68	0.41	-0.41	11.80
FEB	3.75	3.74	6.25	6.23	0.57	-0.57	12.48
MAR	9.47	4.77	15.78	7.95	1.29	-1.29	23.73
TOTAL	39.16	20.85	65.26	34.74	6.06	-6.06	100.02
AVERAGE	5.59	2.98	9.32	4.96	0.87	-0.87	14.29

It appears that system savings were severely impacted by manual operation of the collector pump. It has already been noted that the gross solar energy collected was 55.25 million BTU but only 39.16 million BTU were retained due to inadvertent rejection of collected energy which resulted from early operation of the pump. Using the following assumptions:

(1) The gross collected energy (55.25 million BTU) should have been available for use.

(2) The collected energy was only 6/7 as much as it should have been due to no collector pump operation on Sundays.

(3) The collector pump should have run only 85% as much as it did due to early activation and 24-hour operation during parts of September and October.

Then the monetary savings due to solar would have been:

(7/6) x (55.25 million BTU/0.6) x 979.4 ft^3/million BTU x $4.67/1,000 ft^3 - (0.85 x 6.06 million BTU) x 292.8 kwh/million BTU x 6.48 cents/kwh = 491.37 - 97.73 = $393.63 an increase of over 100%.

Table 7 presents the solar operating energy. As has been noted previously collector subsystem operating energy values for September and October are high. In addition, the other monthly values may be high due to early operation of the collector pump but this is partially offset by no operation on Sundays. In a previous section of this report, it was assumed that the difference was approximately 15%.

Table 7. SOLAR OPERATING ENERGY

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 1982

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	TOTAL SOLAR OPERATING ENERGY
SEP	1.62	1.62
OCT	0.82	0.82
NOV	0.88	0.88
DEC	0.47	0.47
JAN	0.41	0.41
FEB	0.57	0.57
MAR	1.29	1.29
TOTAL	6.06	6.06
AVERAGE	0.87	0.87

Table 8 presents the measured environmental data along with 30-year long-term averages in the Dallas area. The collector is tilted at 27 degrees from the horizontal for this site which is at 33 degrees north latitude. The measured daily incident solar energy was only 86% of the long-term value, indicating a cloudy winter. Ambient temperatures were calculated by two methods: mean of each individual measurement, and average of the daily minimums and maximums (National Weather Service method). In this case, the two methods agreed but were one degree higher than the long-term value. The higher average temperature resulted in less heating degree-days (65°F reference) and more cooling degree-days (65°F reference) than the long-term data.

Table 8. WEATHER CONDITIONS

CRAFTSMAN ENTERPRISES
SEPTEMBER 1981 THROUGH MARCH 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(1)		LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
SEP	1,680	1,735	(78)	77	78	6	0	388	396
OCT	1,079	1,589	(67)	66	68	107	55	166	148
NOV	1,307	1,303	(59)	58	56	202	284	14	11
DEC	1,042	1,147	(48)	49	48	509	521	0	0
JAN	1,166	1,161	(46)	46	45	592	608	2	0
FEB	1,067	1,370	(45)	46	49	545	437	11	0
MAR	1,207	1,625	(62)	61	56	215	314	106	29
TOTAL	-	-	-	-	-	2,176	2,219	687	584
AVERAGE	1,221	1,419	(58)	58	57	311	317	98	83

(1) Values in parentheses are by NWS method.

1.2 SYSTEM OPERATION

1.2.1 TYPICAL SYSTEM OPERATION

Curves showing typical system operation on a bright, partly cloudy day (February 23, 1982) are presented in Figures 4a and 4b. Figure 4a shows the outside ambient temperature, storage temperature, and the insolation on the collector array. The plot also indicates the time during which the collector pump was circulating water through the collectors.

Figure 4b shows storage, collector inlet, and collector outlet temperatures along with times when the collector pump was operating. On this day, the collector pump was manually activated at 7:50 a.m. (all times are Central Standard Time) and turned off at 5:37 p.m. Figure 4b explicitly demonstrates the rejection of energy which occurs during times when the collector outlet temperatures are exceeded by collector inlet temperatures. Positive values for solar energy collection occurred from 8:49 a.m. to 4:59 p.m. On this date there were 1.91 million BTU of solar energy incident, 1.88 million BTU incident during collector flow, 0.98 million BTU collected between 8:49 a.m. and 4:59 p.m., and 0.06 million BTU rejected before positive collection commenced.

The negative spike for collector outlet temperature shortly after startup closely follows a sharp drop in incident radiation. This may also be caused by transient effects occurring at startup.

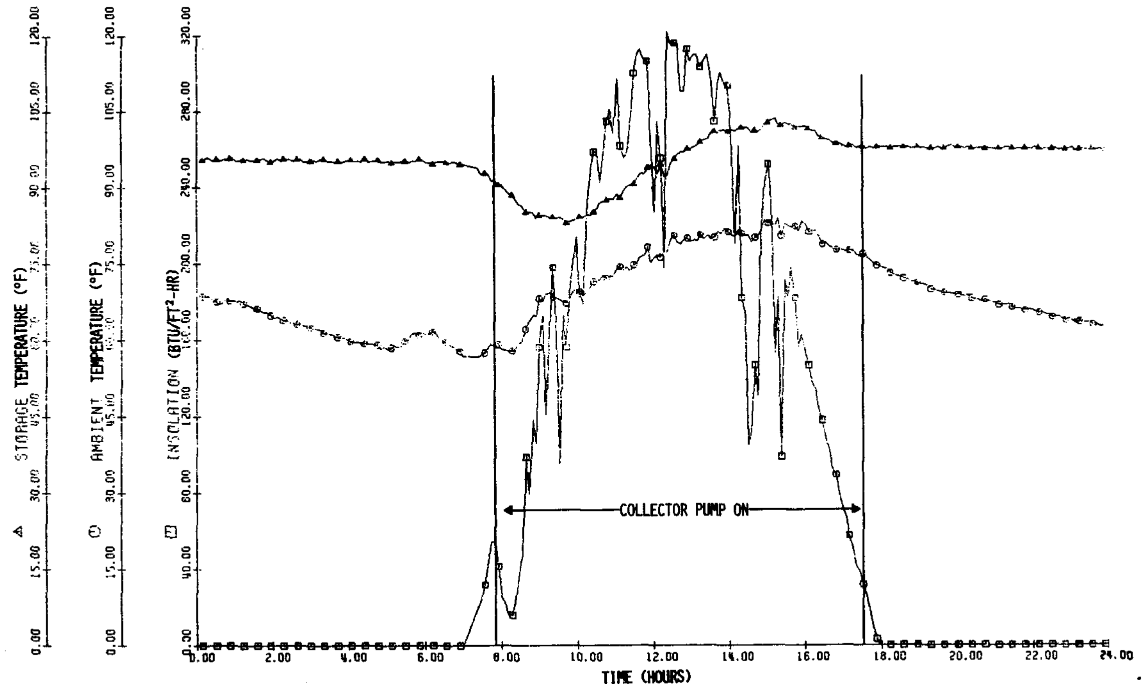


Figure 4a. Typical Insolation Data, Outside Ambient and Storage Temperatures
Craftsman Enterprises
February 23, 1982

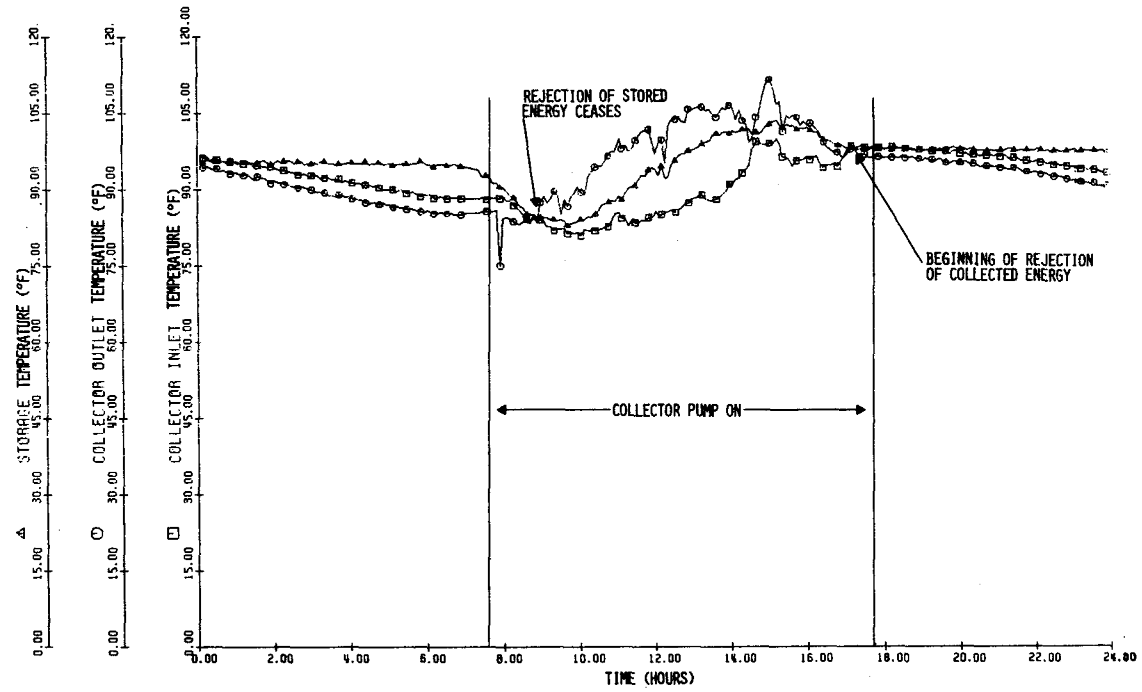


Figure 4b. Typical Storage and Collector Array Inlet/Outlet Temperatures
Craftsman Enterprises
February 23, 1982

Figure 4c plots the hot water consumption profile for February 23, 1982, and the average daily consumption profile for the reporting period. The hot water consumption on February 23, 1982 totaled 2,119 gallons and the daily average water use was 1,485 gallons/day. On February 23, 1982, the two hours with the highest consumptions occurred right after collector startup when the storage temperature was 95°F. The consumption between 8:00 a.m. and 10:00 a.m. quickly reduced the storage temperature to 83°F. Storage temperatures began to increase again during the low consumption hour between 10:00 a.m. and 11:00 a.m. In general, the average daily consumption profile does not result in optimal use of solar energy since the profile is skewed toward the early morning hours. A normal Gaussian distribution around noon may have resulted in better solar utilization.

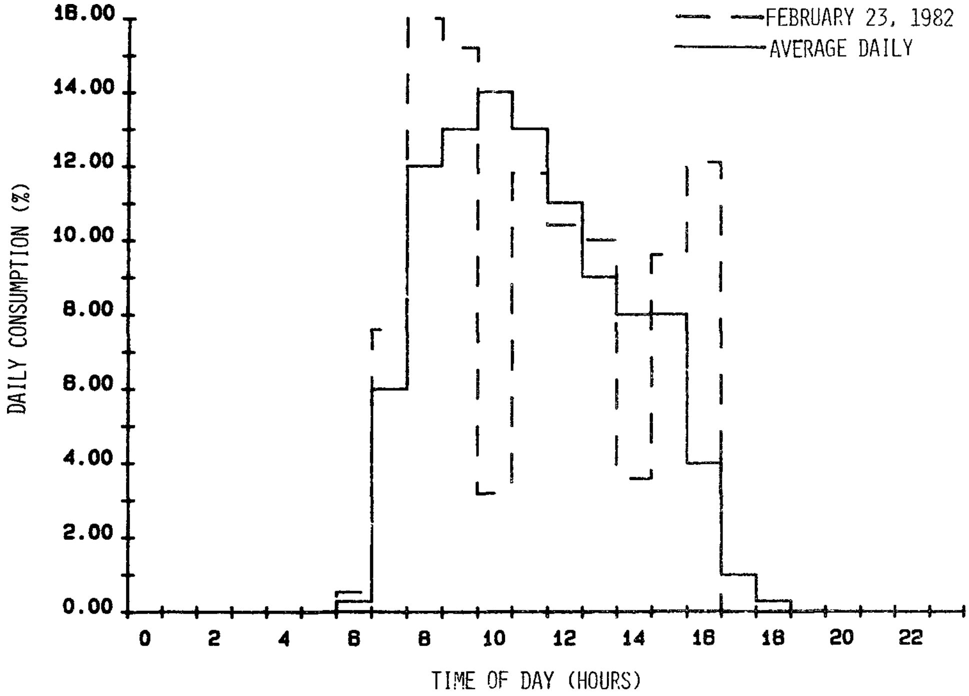


Figure 4c. Consumption Profile for February 23, 1982 and Average Daily Hot Water Consumption Profile
Craftsman Enterprises
September 1981 through March 1982

1.2.2 SYSTEM OPERATING SEQUENCE

Figure 5 presents a bar chart showing the system operating sequences for February 23, 1982. As indicated in Section 1.2.1, the collector pump was turned on one hour early and ran 45 minutes longer than necessary. Adequate incident insolation for the system to have a net gain is approximately 100 BTU/ft^2-hr and was available exactly an hour after collector pump startup. Incident insolation dropped below the 100 BTU/ft^2-hr level one hour before the collector pump was turned off.

Gas was used for the entire day to make up standby losses from the two 100-gallon tanks. The Domestic Hot Water (DHW) booster pump ran from 7:23 a.m. to 4:43 p.m.

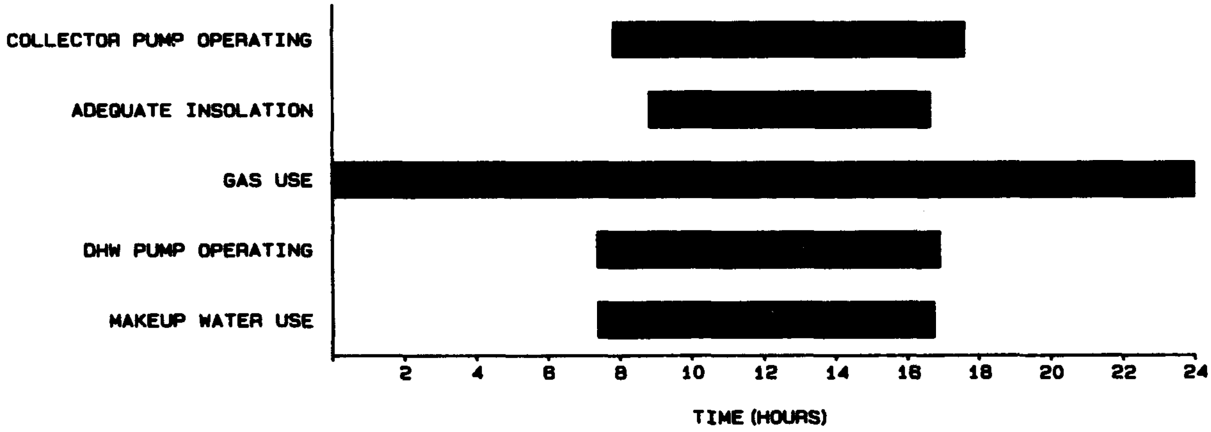


Figure 5. Typical System Operating Sequence
Craftsman Enterprises
February 23, 1982

1.3 SOLAR ENERGY UTILIZATION

Figure 6 shows the use of solar energy and the percentage of losses of solar energy at the different stages through the system, from total incident radiation to the load. Threshold losses are very high. Forty percent of the total incident energy impinged on the collector array when the collector pump was not operational. This mainly resulted from the system not being operated on Sundays and on a number of weekdays during December and January. From NSDN data (Reference 14), typical threshold losses for hot water systems are 20%. The collected energy was 15% of the total incident or 25% of the operational incident. All solar energy collected was delivered to storage and all energy delivered to storage is considered energy delivered to the load.

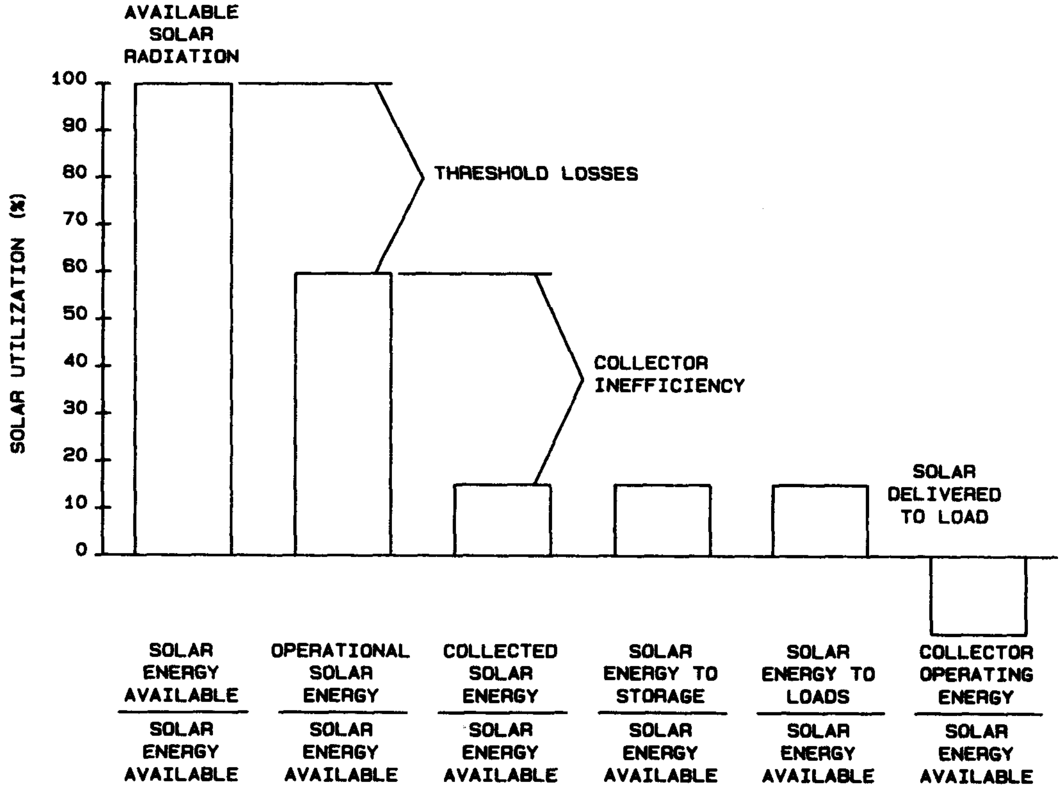


Figure 6. Solar Energy Use
Craftsman Enterprises
September 1981 through March 1982

SECTION 2

REFERENCES

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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. Monthly Performance Report, Craftsman Enterprises, September 1981, Vitro Laboratories, Silver Spring, Maryland.

7. Monthly Performance Report, Craftsman Enterprises, October 1981, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, Craftsman Enterprises, November 1981, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, Craftsman Enterprises, December 1981, Vitro Laboratories, Silver Spring, Maryland.

11. Monthly Performance Report, Craftsman Enterprises, January 1982, Vitro Laboratories, Silver Spring, Maryland.

12. Monthly Performance Report, Craftsman Enterprises, February 1982, Vitro Laboratories, Silver Spring, Maryland.

13. Monthly Performance Report, Craftsman Enterprises, March 1982, 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.

*14. Comparative Report: Performance of Solar Hot Water Systems. 1980-1981, SOLAR/0024-82/41, Vitro Laboratories, Silver Spring, Maryland.

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

APPENDIX A

SYSTEM DESCRIPTION

The Craftsman Enterprises site is an industrial laundry located in Dallas, Texas. The system was designed so that collected and recycled solar energy would satisfy approximately 60% of the 1,100 gallon per day hot water laundry process demand. Delivered hot water temperature to the laundry is designed to be about 150°F. Incoming city water is preheated in a wastewater sump pit by means of a 100-foot-long heat exchanger pipe.

Collector - The solar collector array consists of 43 flat-plate, single-glazed S-Systems Collectors. These collectors utilize Olin roll bond absorbers painted flat black, and have a plastic glazing reinforced with fiberglass. Water is used as the heat transfer medium.

The collector dimensions are 96.75 inches by 35 inches, which provides a gross collector area of 1,011 square feet which is used in the calculation of performance. The collector array faces one degree west of due south with a tilt angle of 27 degrees from the horizontal.

Storage - The Craftsman Enterprises storage tank is composed of a 2,000-gallon steel tank with one inch of polyurethane insulation. The storage tank is located outdoors, and there is a six foot by three foot area of the tank surface that is uninsulated adjacent to the building. Preheated water can be provided by both the heat recovery system (wastewater) and the solar collector array to the storage tank where the two sources of energy are mixed for delivery to the auxiliary water heaters.

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

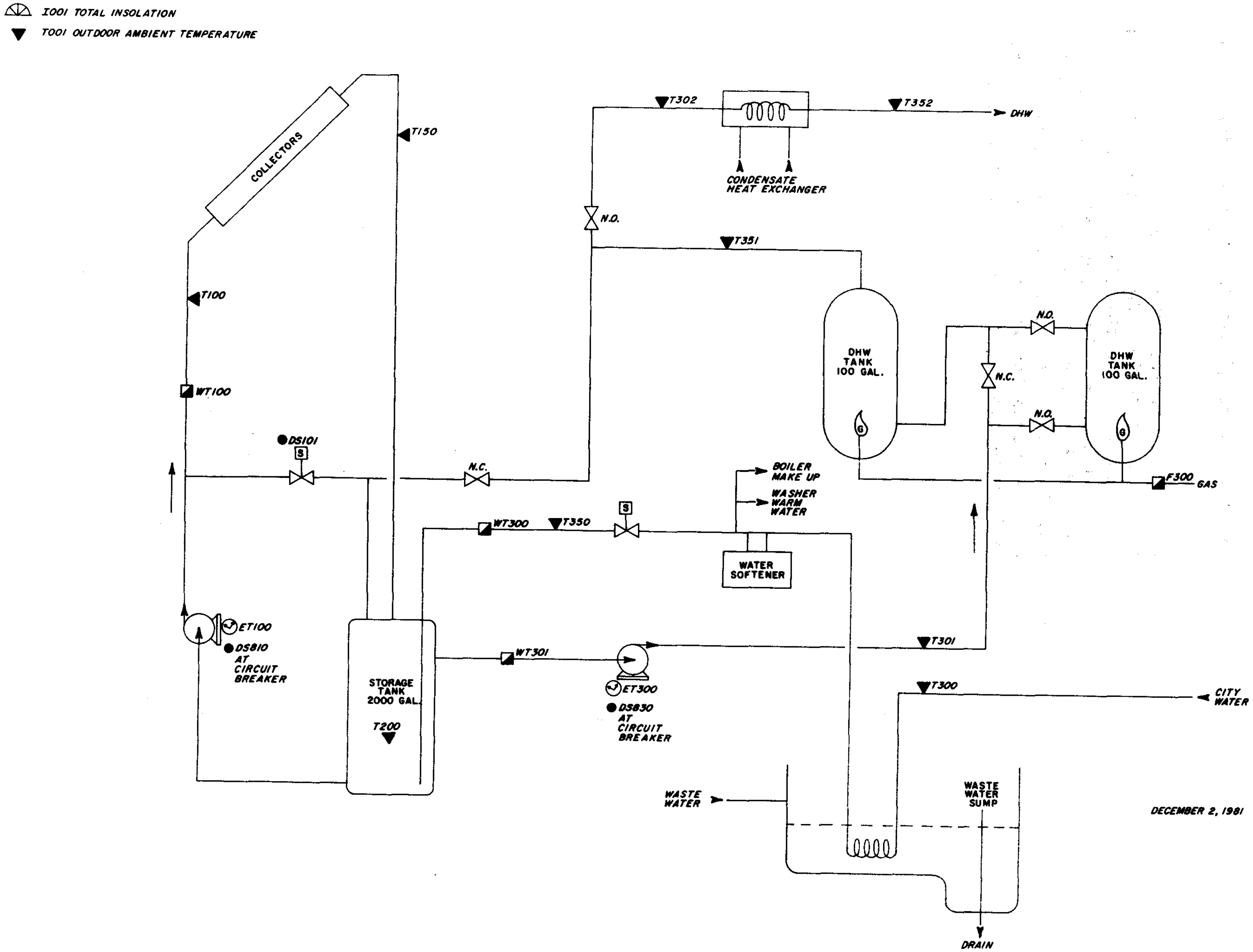
Equipment/Components	Manufacturer
Solar Collectors	S-Systems
Control System	Hawthorne
Solar Pump	Dayton 3/4-hp
DHW Pump	Dayton 2-hp
DHW Tank #1	Mor-Flo 100-gallon, natural gas
DHW Tank #2	American Ameriglas 100-gallon, natural gas

Laundry Hot Water Heating - City water enters the system through a wastewater sump pit heat exchanger, which is 100 feet of submerged pipe. The water can then be preheated by the solar collector array via the bottom of the 2,000-gallon solar storage tank. Water is finally heated by two natural-gas-fired water heaters and then by a condensate heat exchanger which is piped to a steam boiler.

The system, shown schematically in Figure A-1, has two modes of operation for solar energy collection and process water heating.

Mode 1 - Collector-to-Storage - During this mode of operation, water is pumped from solar thermal storage through the collector array and back into storage. This mode is activated when the temperature of the collector array outlet exceeds the storage temperature by 18°F and continues until this differential temperature drops below 2°F.

Mode 2 - Hot Water Demand - This mode is activated when there is a demand by the laundry for hot water. City water entering the hot water system is preheated using thermal energy from wastewater in the 275-gallon sump pit by way of a 100-foot submerged heat exchanger pipe. The temperature of the city water is raised to a typical range of 80°F-95°F before entering the solar thermal storage. As water is drawn from solar thermal storage, it is heated by either one or two natural-gas-fired 100-gallon water heaters. Additional energy is supplied from steam condensate flowing through a heat exchanger.



DECEMBER 2, 1981

Figure A-1. Craftsman Enterprises Solar Energy System Schematic

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

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

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

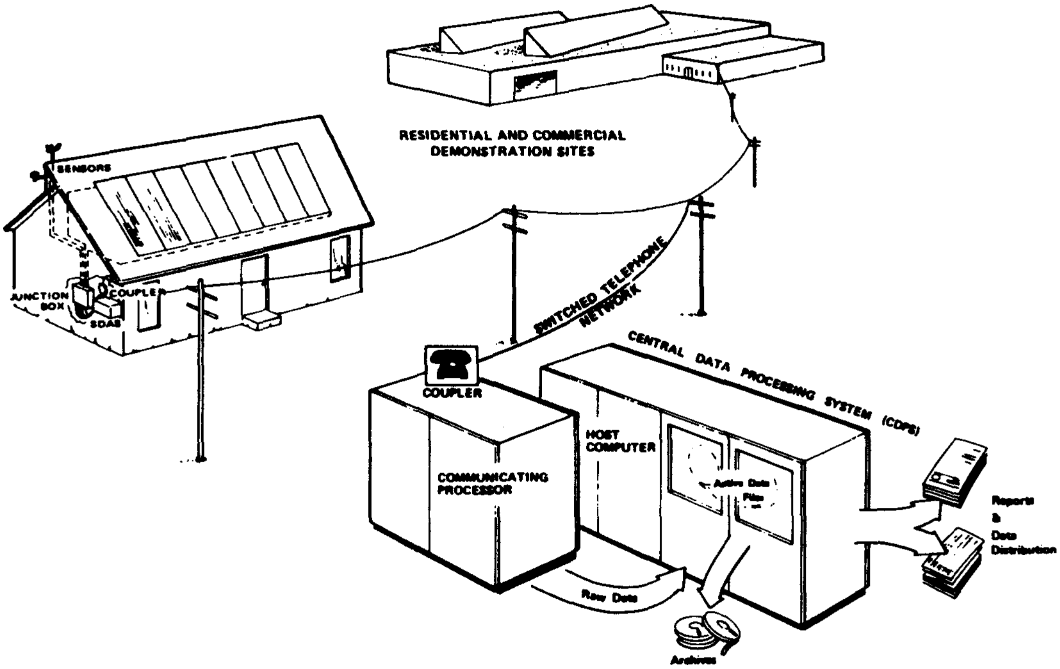


Figure B-1. The National Solar Data Network

DATA COLLECTION AND PROCESSING

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

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

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

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

DATA ANALYSIS

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

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

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

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

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

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

REPORTING

The performance of the Craftsman Enterprises solar energy system from September 1981 through March 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:

- September 1981
- October 1981
- November 1981
- December 1981
- January 1982
- February 1982
- March 1982

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

Section 2. Solar Terminology

Section 3. General Acronyms

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.

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* 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.

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* 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.

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* 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.

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* 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.

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* 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.

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* Primary Performance Factors

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

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* 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 above 65°F.
Cooling Tower	A heat exchanger that transfers waste heat to outside ambient air.
Diffuse Radiation	Solar Radiation which is scattered by air molecules, dust, or water droplets and incapable of being focused.
Drain Down	An arrangement of sensors, valves and actuators to automatically drain the solar collectors and collector piping to prevent freezing in the event of cold weather.
Duct Heating Coil	A liquid-to-air heat exchanger in the duct distribution system.
Effective Heat Transfer Coefficient	The heat transfer coefficient, per unit plate area of a collector, which is a measure of the total heat losses per unit area from all sides, top, back, and edges.
Energy Gain	The thermal energy gained by the collector transfer fluid. The thermal energy output of the collector.

Energy Savings	The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.
Expansion Tank	A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as 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: $\frac{Ti-Ta}{I} \left(\frac{°F \text{ x hr. x sq. ft.}}{BTU}\right)$
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 x 10^{-4} kwh of electrical energy.
COP	Coefficient of Performance. The ratio of total load to solar-source energy.
DHW	Domestic Hot Water.
ECSS	Energy Collection and Storage System.
HWS	Domestic or Service Hot Water Subsystem.
KWH	Kilowatt Hours, a measure of electrical energy. The product of kilowatts of electrical power applied to a load times the hours it is applied. One kwh is equivalent to 3,413 BTU of heat energy.
NSDN	National Solar Data Network.
SCS	Space Cooling Subsystem.
SHS	Space Heating Subsystem.
SOLMET	Solar Radiation/Meteorology Data.

APPENDIX D

PERFORMANCE EQUATIONS

CRAFTSMAN ENTERPRISES

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

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

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.

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* See Appendix B.

For an air system ΔH is generally given by

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

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

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

For electrical power, a general example is

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

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

Letter Designations

C or CP = Specific Heat

D = Direction or Position

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

ENVIRONMENTAL FACTORS

AVERAGE AMBIENT TEMPERATURE (°F)

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

U.S. WEATHER STATION AVERAGE AMBIENT TEMPERATURE (°F)

$$TAVE = \Sigma(T001 \text{ daily maximum} + T001 \text{ daily minimum})/2$$

HEATING DEGREE-DAYS/COOLING DEGREE-DAYS

$$CDD = \Sigma\ TAVE - 65^{\circ}F$$

$$\text{if } TAVE > 65^{\circ}F$$

$$HDD = \Sigma\ 65^{\circ}F - TAVE$$

$$\text{if } TAVE < 65^{\circ}F$$

DAYTIME AVERAGE AMBIENT TEMPERATURE (°F)

$$TDA = (1/360) \times \Sigma\ T001 \times \Delta\tau \quad (\text{for } \pm 3 \text{ hours of solar noon})$$

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

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

INCIDENT SOLAR ENERGY ON THE ARRAY (BTU)

$$SEA = CLAREA \times SE$$

where $CLAREA = \text{COLLECTOR AREA} = 1{,}011\ FT^2$

COLLECTOR SUBSYSTEM FACTORS

ECSS OPERATING ENERGY (BTU)

$$\text{CSOPE} = \text{ED100} \times 56.8833 \times 1.288$$

where 1.288 is measured power use of the collector pump, and

$$\text{ED100} = \text{ET100 (present)} - \text{ET100 (previous)}$$

NET SOLAR ENERGY COLLECTED BY THE ARRAY (BTU)

$$\text{SECA} = \Sigma\ \text{M100} \times \text{HWD (T150, T100)}$$

GROSS SOLAR ENERGY COLLECTED BY THE ARRAY (BTU)

$$\text{SECAG} = \text{SECA}$$

if SECA > 0

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

$$\text{SEC} = \text{SECA/CLAREA}$$

OPERATIONAL INCIDENT SOLAR ENERGY (BTU)

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

COLLECTOR EFFICIENCY (%)

$$\text{CLEF} = (\text{SECA/SEA}) \times 100$$

OPERATIONAL COLLECTOR EFFICIENCY (%)

$$\text{CLEFOP} = (\text{SECA/SEOP}) \times 100$$

STORAGE SUBSYSTEM FACTORS

ENERGY DELIVERED TO STORAGE (BTU)

$$\text{STEI} = \text{SECA} + \text{SUMP}$$

where $\text{SUMP} = \Sigma(\text{M300} \times \text{HWD (T350, T300)} \times \Delta\tau)$

CHANGE IN STORED ENERGY (BTU)

$$\text{STECH} = \text{Storage Capacity} \times (\text{RHO(T)} \times C_p\text{(T)} \times \text{T} - (\text{RHO}(T_p) \times C_p(T_p) \times T_p))$$

where RHO(T) and C_p(T) are the density and specific heat as functions of temperature and T and T_p are the average temperatures of storage for the current and previous hours

AVERAGE TEMPERATURE OF STORAGE (^oF)

$$TST = (1/60) \times \Sigma\ T200 \times \Delta\tau$$

THE FOLLOWING STORAGE PERFORMANCE FACTORS WERE NOT VALID DURING THE CURRENT REPORTING PERIOD BECAUSE OF INVALID TEMPERATURE SENSOR T301.

SOLAR ENERGY WITHDRAWN FROM STORAGE (BTU)

$$STEO = \Sigma(M301 \times HWD\ (T301,\ T350)) \times \Delta\tau$$

STORAGE EFFICIENCY (%)

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

STORAGE LOSS (BTU)

$$STLOSS = STEI - STEO - STECH$$

HOT WATER SUBSYSTEM FACTORS

HOT WATER CONSUMED (GAL)

$$HWCSM = \Sigma\ WD301$$

where $WD301 = WT301\ (\text{current}) - WT301\ (\text{previous})$

SUPPLY WATER TEMPERATURE (^oF)

$$TSW = \frac{M300 \times T300}{M300}$$

The mass flow is used to insure that the supply water temperature is recorded only when there is flow.

SUMP PIT OUTLET TEMPERATURE (^oF)

$$TSUMP = \frac{M300 \times T350}{M300}$$

The mass flow is used to insure that the supply water temperature is recorded only when there is flow.

DELIVERY WATER TEMPERATURE (^oF)

$$THW = \frac{M301 \times T352}{M301}$$

The mass flow is used to insure that the supply water temperature is recorded only when there is flow.

HOT WATER SOLAR ENERGY USED (BTU)

HWSE = SECA

HOT WATER AUXILIARY THERMAL ENERGY GAINED AT THE TANKS (BTU)

$HWATTK = \Sigma (FD300 \times FCONST \times 0.6)$

where FD300 = F300 (current) - F300 (previous)

FCONST = 1,021 BTU/ft^3

0.6 is assumed efficiency of conversion

HOT WATER AUXILIARY THERMAL ENERGY GAINED AT CONDENSATE HEAT EXCHANGER (BTU)

$CONDHX = \Sigma\ M301 \times HWD\ (T352, T302) \times \Delta\tau$

TOTAL HOT WATER THERMAL ENERGY (BTU)

HWAT = HWATTK + CONDHX

RECLAIMED ENERGY AT THE SUMP PIT (BTU)

$SUMP = \Sigma\ M300 \times HWD\ (T350, T300) \times \Delta\tau$

TOTAL HOT WATER LOAD (BTU)

HWL = HWAT + STEI

SECONDARY HOT WATER LOAD (BTU)

HWL2 = HWAT + HWSE

TOTAL HOT WATER DEMAND (BTU)

$HWDM = \Sigma\ M301 \times HWD\ (T352, T300) \times \Delta\tau$

SECONDARY HOT WATER DEMAND (BTU)

$HWDM2 = \Sigma\ M301 \times HWD\ (T352, T350) \times \Delta\tau$

HOT WATER OPERATING ENERGY (BTU)

$HWOPE = 56.8833 \times \Sigma\ ED300 \times \Delta\tau$

where ED300 = ET300 (current) - ET300 (previous)

HOT WATER SOLAR FRACTION (%)

HWSFR = (HWSE/HWL2) x 100

HOT WATER AUXILIARY FOSSIL ENERGY (BTU)

HWAF = HWAT/0.6

HOT WATER SAVINGS FOSSIL (BTU)

HWSVF = HWSE/0.6

RECOVERY SYSTEM SAVINGS FOSSIL (BTU)

RCSVF = SUMP/0.6

SYSTEM LEVEL FACTORS

SYSTEM LOAD (BTU)

SYSL = HWL

SECONDARY SYSTEM LOAD (BTU)

SYSL2 = HWL2

SOLAR ENERGY USED (BTU)

SEL = HWSE

SYSTEM SOLAR FRACTION (%)

SFR = HWSFR

AUXILIARY THERMAL ENERGY (BTU)

AXT = HWAT

AUXILIARY FOSSIL ENERGY (BTU)

AXF = HWAF

SYSTEM OPERATING ENERGY (BTU)

SYSOPE = CSOPE + HWOPE

SOLAR SPECIFIC OPERATING ENERGY (BTU)

SYSOPE1 = CSOPE

TOTAL ENERGY CONSUMED (BTU)

TECSM = SYSOPE + AXF + SECA

TOTAL FOSSIL ENERGY SAVINGS (BTU)

TSVF = HWSVF + RCSVF

TOTAL ELECTRICAL ENERGY SAVINGS (BTU)

TSVE = -SYSOPE1

SYSTEM PERFORMANCE FACTOR

SYSPF = SYSL/(AXF + SYSOPE x 3.33)

SOLAR SAVINGS RATIO

SSSR = (SEL - SYSOPE1)/SYSL2

ECSS CONVERSION EFFICIENCY

CSCEF = SEL/SEA

APPENDIX E

CRAFTSMAN ENTERPRISES LONG-TERM WEATHER DATA

COLLECTOR TILT: 27 DEGREES
LATITUDE: 33 DEGREES

LOCATION: DALLAS, TEXAS
COLLECTOR AZIMUTH: ONE DEGREE

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1709.	822.	0.48110	1.411	1161.	608	0	45.
FEB	2137.	1073.	0.50198	1.277	1370.	437	0	49.
MAR	2661.	1423.	0.53490	1.141	1625.	314	29	56.
APR	3166.	1626.	0.51360	1.014	1649.	71	113	66.
MAY	3490.	1888.	0.54092	0.934	1764.	0	273	74.
JUN	3610.	2135.	0.59138	0.897	1916.	0	498	82.
JUL	3542.	2124.	0.59963	0.913	1938.	0	642	86.
AUG	3283.	1950.	0.59418	0.981	1913.	0	645	86.
SEP	2837.	1589.	0.56010	1.092	1735.	0	396	78.
OCT	2286.	1276.	0.55798	1.245	1589.	55	148	68.
NOV	1807.	936.	0.51830	1.392	1303.	284	11	56.
DEC	1587.	782.	0.49254	1.467	1147.	521	0	48.

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

CONVERSION FACTORS

Energy Conversion Factors

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

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

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

APPENDIX G

SENSOR TECHNOLOGY

Temperature Sensors

Temperatures are measured by a Minco Products S53P platinum Resistance Temperature Detector (RTD). Because the resistance of platinum wire varies as a function of temperature, measurement of the resistance of a calibrated length of platinum wire can be used to accurately determine the temperature of the wire. This is the principle of the platinum RTD which utilizes a tiny coil of platinum wire encased in a copper-tipped probe to measure temperature.

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

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

Nominal Resistance @ 25°C:	100 ohms
No. of Leads:	3
Electrical Connection:	Wheatstone Bridge
Time Constant	1.5 seconds max. in water at 3 fps
Self Heating:	27 mw/°F

WIND SENSOR

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

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

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

HUMIDITY SENSORS

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

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

INSOLATION SENSORS

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

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

LIQUID FLOW SENSORS (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"

APPENDIX H

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                  MONTHLY REPORT:  FEBRUARY 1982
               SITE SUMMARY:  CRAFTSMAN ENTERPRISES - P2825

                                                         CONVENTIONAL UNITS
___________________________________________________________________________
GENERAL SITE DATA:
   INCIDENT SOLAR ENERGY                                 30.196 MILLION BTU
                                                          29863 BTU/SQ.FT.
   COLLECTED SOLAR ENERGY                                 3.753 MILLION BTU
                                                           3712 BTU/SQ.FT.
   AVERAGE AMBIENT TEMPERATURE                               45 DEGREES F
   AVERAGE BUILDING TEMPERATURE                            N.A. DEGREES F
   ECSS SOLAR CONVERSION EFFICIENCY                        0.12
   ECSS OPERATING ENERGY                                  0.566 MILLION BTU
   STORAGE EFFICIENCY                                      0.00 PERCENT
   EFFECTIVE HEAT TRANSFER COEFFICIENT                     N.A. BTU/DEG F-
                                                                SQ FT-HR
   TOTAL SYSTEM OPERATING ENERGY                          1.544 MILLION BTU
   TOTAL ENERGY CONSUMED                                 92.446 MILLION BTU
___________________________________________________________________________
SUBSYSTEM SUMMARY:
                        HOT WATER       HEATING     COOLING      SYSTEM TOTAL
   LOAD                    59.720          N.A.        N.A.   59.720 MILLION BTU
   SOLAR FRACTION               0          N.A.        N.A.        7 PERCENT
   SOLAR ENERGY USED        3.753          N.A.        N.A.    3.753 MILLION BTU
   OPERATING ENERGY         0.977          N.A.        N.A.    1.544 MILLION BTU
   AUX. THERMAL ENERGY     52.289          N.A.        N.A.   52.289 MILLION BTU
   AUX. ELECTRIC FUEL        N.A.          N.A.        N.A.     N.A. MILLION BTU
   AUX. FOSSIL FUEL        87.149          N.A.        N.A.   87.149 MILLION BTU
   ELECTRICAL SAVINGS        N.A.          N.A.        N.A.   -0.566 MILLION BTU
   FOSSIL SAVINGS           6.255          N.A.        N.A.   12.466 MILLION BTU
___________________________________________________________________________
SYSTEM PERFORMANCE FACTOR:                 0.65
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS:     0.44
___________________________________________________________________________

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
           SOLAR/0004-81/18
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MONTHLY REPORT: FEBRUARY 1982
SITE SUMMARY: CRAFTSMAN ENTERPRISES - P2825

GENERAL SITE DATA:	SI UNITS
INCIDENT SOLAR ENERGY	31.857 GIGA JOULES 339120 KJ/SQ.M.
COLLECTED SOLAR ENERGY	3.959 GIGA JOULES 42149 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	7 DEGREES C
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.12
ECSS OPERATING ENERGY	0.598 GIGA JOULES
STORAGE EFFICIENCY	0.00 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	N.A. W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	1.628 GIGA JOULES
TOTAL ENERGY CONSUMED	97.530 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	63.005	N.A.	N.A.	63.005 GIGA JOULES
SOLAR FRACTION	0	N.A.	N.A.	7 PERCENT
SOLAR ENERGY USED	3.959	N.A.	N.A.	3.959 GIGA JOULES
OPERATING ENERGY	1.031	N.A.	N.A.	1.628 GIGA JOULES
AUX. THERMAL ENG	55.165	N.A.	N.A.	55.165 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	91.942	N.A.	N.A.	91.942 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.598 GIGA JOULES
FOSSIL SAVINGS	6.599	N.A.	N.A.	13.152 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.65
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 0.44

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

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 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	1.123	42	0.335	N	0.044	N	0.298
2	0.519	46	-0.264	O	0.046	O	-0.509
3	0.270	31	-0.280	T	0.041	T	-1.038
4	0.251	29	-0.021		0.005		-0.085
5	0.159	23	-0.059	A	0.021	A	-0.371
6	1.774	23	0.000	P	0.000	P	0.000
7	1.598	36	0.000	P	0.000	P	0.000
8	0.082	40	-0.002	L	0.001	L	-0.024
9	1.242	31	-0.004	I	0.025	I	-0.003
10	0.555	32	-0.231	C	0.049	C	-0.417
11	1.672	41	0.204	A	0.030	A	0.122
12	0.401	41	0.000	B	0.000	B	0.000
13	1.106	39	0.000	L	0.000	L	0.000
14	1.822	47	0.000	E	0.000	E	0.000
15	1.065	61	0.011		0.001		0.011
16	1.961	61	0.883		0.036		0.450
17	0.866	49	0.241		0.032		0.278
18	1.702	50	0.646		0.037		0.380
19	1.858	56	0.778		0.031		0.419
20	0.938	60	0.000		0.000		0.000
21	2.040	62	0.000		0.000		0.000
22	1.968	70	0.937		0.044		0.476
23	1.908	69	0.765		0.043		0.401
24	0.195	58	-0.123		0.038		-0.632
25	0.112	39	-0.053		0.006		-0.474
26	0.279	34	-0.007		0.037		-0.026
27	0.984	39	0.000		0.000		0.000
28	1.749	45	-0.002		0.000		-0.001
SUM	30.196	-	3.753	N.A.	0.566	N.A.	-
AVG	1.078	45	0.134	N.A.	0.020	N.A.	0.124
PFRV	0.9955	0.9955	0.9955	N.A.	0.9955	N.A.	1.0000

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 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	1.123	1.121	0.335	46	0.298	0.299
2	0.519	0.518	-0.264	53	-0.509	-0.509
3	0.270	0.257	-0.280	31	-1.038	-1.090
4	0.251	0.003	-0.021	30	-0.085	-8.315
5	0.159	0.036	-0.059	21	-0.371	-1.653
6	1.774	0.000	0.000	27	0.000	0.000
7	1.598	0.000	0.000	43	0.000	0.000
8	0.082	0.002	-0.002	41	-0.024	-0.913
9	1.242	0.741	-0.004	31	-0.003	-0.005
10	0.555	0.555	-0.231	37	-0.417	-0.417
11	1.672	1.500	0.204	49	0.122	0.136
12	0.401	0.000	0.000	42	0.000	0.000
13	1.106	0.000	0.000	45	0.000	0.000
14	1.822	0.000	0.000	55	0.000	0.000
15	1.065	0.009	0.011	67	0.011	1.257
16	1.961	1.850	0.883	69	0.450	0.477
17	0.866	0.760	0.241	54	0.278	0.317
18	1.702	1.639	0.646	56	0.380	0.394
19	1.858	1.646	0.778	68	0.419	0.473
20	0.938	0.000	0.000	69	0.000	0.000
21	2.040	0.000	0.000	75	0.000	0.000
22	1.968	1.964	0.937	81	0.476	0.477
23	1.908	1.881	0.765	78	0.401	0.407
24	0.195	0.194	-0.123	54	-0.632	-0.635
25	0.112	0.035	-0.053	39	-0.474	-1.504
26	0.279	0.258	-0.007	35	-0.026	-0.028
27	0.984	0.000	0.000	44	0.000	0.000
28	1.749	0.037	-0.002	55	-0.001	-0.065
SUM	30.196	15.005	3.753	-	-	-
AVG	1.078	0.536	0.134	50	0.124	0.250
PFRV	0.9955	0.9955	0.9955	0.9955	0.9955	0.9955

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 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	0.528	0.000#	N	62	N
2	-0.108	0.000#	O	63	O
3	-0.137	0.000#	T	58	T
4	0.109	0.000#		56	
5	0.047	0.000#	A	54	A
6	0.023	0.000#	P	52	P
7	0.000	0.000#	P	51	P
8	0.184	0.000#	L	51	L
9	0.201	0.000#	I	52	I
10	-0.067	0.000#	C	53	C
11	0.419	0.000#	A	55	A
12	0.146	0.000#	B	52	B
13	0.083	0.000#	L	50	L
14	0.010	0.000#	E	50	E
15	0.215	0.000#		52	
16	1.099	0.000#		64	
17	0.367	0.000#		72	
18	0.816	0.000#		79	
19	0.918	0.000#		92	
20	0.086	0.000#		87	
21	0.000	0.000#		79	
22	1.167	0.000#		87	
23	0.972	0.000#		95	
24	0.014	0.000#		82	
25	0.137	0.000#		65	
26	0.149	0.000#		58	
27	0.125	0.000#		56	
28	-0.011	0.000#		55	
SUM	7.492	0.000	0.000	-	-
AVG	0.268	0.000	0.000	64	N.A.
PFRV	0.9940	0.0000	N.A.	0.9955	N.A.

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 1982

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	2.949	0	2.028	N	0.335	0.050	2.422
2	2.275	0	1.941	O	-0.264	0.046	2.382
3	2.056	0	1.715	T	-0.280	0.041	2.193
4	2.007	0	1.625		-0.021	0.038	1.898
5	2.066	0	1.487	A	-0.059	0.042	2.018
6	0.766	0	0.384	P	0.000	0.016	0.744
7	0.259	0	0.001	P	0.000	0.000	0.259
8	3.360	0	2.506	L	-0.002	0.050	3.175
9	2.847	0	2.112	I	-0.004	0.045	2.646
10	2.285	0	1.789	C	-0.231	0.050	2.352
11	2.681	0	1.905	A	0.204	0.041	2.263
12	3.217	0	2.378	B	0.000	0.041	3.133
13	1.582	0	1.093	L	0.000	0.031	1.499
14	0.459	0	0.083	E	0.000	0.005	0.448
15	2.998	0	2.167		0.011	0.047	2.782
16	3.541	0	2.158		0.883	0.045	2.443
17	2.217	0	1.547		0.241	0.034	1.851
18	2.938	0	1.851		0.646	0.045	2.122
19	2.566	0	1.636		0.778	0.044	1.649
20	1.112	0	0.927		0.000	0.023	1.027
21	0.297	0	0.000		0.000	0.000	0.297
22	3.337	0	2.291		0.937	0.047	2.171
23	2.953	0	2.121		0.765	0.045	1.981
24	1.824	0	1.716		-0.123	0.041	1.810
25	2.440	0	1.885		-0.053	0.042	2.303
26	2.416	0	1.861		-0.007	0.040	2.267
27	1.964	0	1.530		0.000	0.029	1.839
28	0.306	0	0.000		-0.002	0.000	0.317
SUM	59.720	-	42.738	-	3.753	0.977	52.289
AVG	2.133	0	1.526	N.A.	0.134	0.035	1.867
PFRV	0.9955	0.9955	0.9955	N.A.	0.9955	0.9955	0.9955

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 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	N	4.036	N	0.558	48	163	N	2102	N
2	O	3.971	O	-0.440	47	163	O	2009	O
3	T	3.655	T	-0.467	46	166	T	1726	T
4		3.164		-0.036	45	164		1683	
5	A	3.364	A	-0.098	45	164	A	1504	A
6	P	1.239	P	0.000	44	172	P	361	P
7	P	0.432	P	0.000	43	193	P	1	P
8	L	5.292	L	-0.003	44	153	L	2746	L
9	I	4.410	I	-0.006	44	158	I	2213	I
10	C	3.920	C	-0.385	43	158	C	1885	C
11	A	3.771	A	0.340	43	149	A	2163	A
12	B	5.222	B	0.000	44	143	B	2891	B
13	L	2.498	L	0.000	43	162	L	1112	L
14	E	0.747	E	0.000	45	167	E	82	E
15		4.637		0.019	45	153		2417	
16		4.071		1.471	46	158		2323	
17		3.084		0.401	46	165		1570	
18		3.536		1.077	46	167		1849	
19		2.748		1.297	47	169		1605	
20		1.711		0.000	48	174		882	
21		0.496		0.000	47	182		0	
22		3.618		1.562	48	165		2367	
23		3.302		1.275	49	169		2119	
24		3.016		-0.205	49	167		1757	
25		3.838		-0.088	48	162		1995	
26		3.778		-0.012	47	158		2024	
27		3.066		0.000	47	156		1677	
28		0.529		-0.004	54	84		1	
SUM	N.A.	87.149	N.A.	6.255	-	-	N.A.	45064	N.A.
AVG	N.A.	3.112	N.A.	0.223	46	160	N.A.	1609	N.A.
PFRV	N.A.	0.9955	N.A.	0.9955	0.9940	0.9955	N.A.	0.9955	N.A.

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

MONTHLY REPORT: CRAFTSMAN ENTERPRISES - P2825 FEBRUARY 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	1111	N	42	46	N	N	N
2	513	O	46	53	O	O	O
3	267	T	31	31	T	T	T
4	248		29	30			
5	157	A	23	21	A	A	A
6	1754	P	23	27	P	P	P
7	1580	P	36	43	P	P	P
8	81	L	40	41	L	L	L
9	1228	I	31	31	I	I	I
10	549	C	32	37	C	C	C
11	1653	A	41	49	A	A	A
12	396	B	41	42	B	B	B
13	1093	L	39	45	L	L	L
14	1802	E	47	55	E	E	E
15	1053		61	67			
16	1939		61	69			
17	857		49	54			
18	1684		50	56			
19	1837		56	68			
20	927		60	69			
21	2017		62	75			
22	1946		70	81			
23	1887		69	78			
24	193		58	54			
25	110		39	39			
26	276		34	35			
27	973		39	44			
28	1730		45	55			
SUM	29863	N.A.	-	-	-	-	-
AVG	1067	N.A.	45	50	N.A.	N.A.	N.A.
PFRV	0.9955	N.A.	0.9955	0.9955	N.A.	N.A.	N.A.

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