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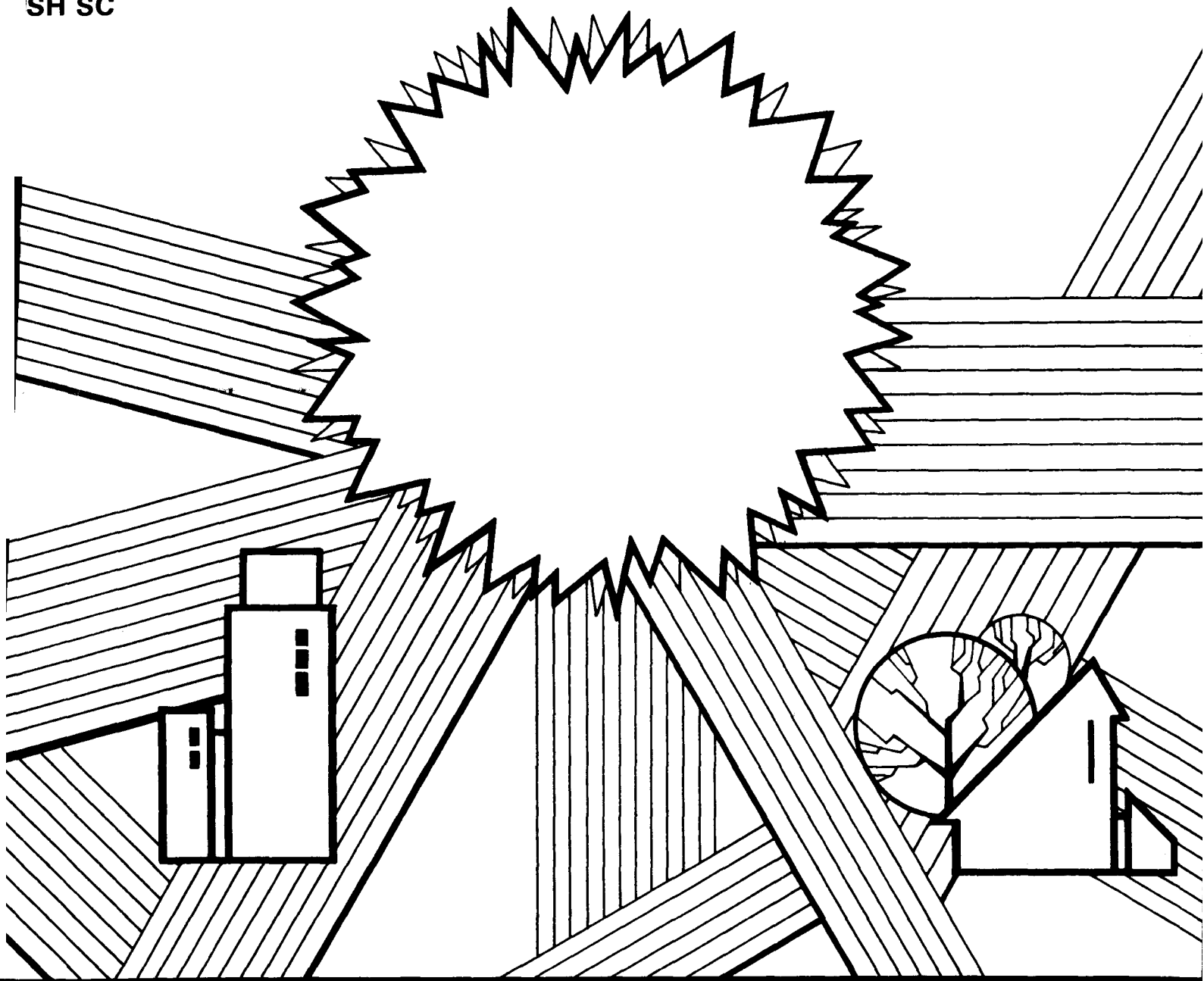
# **SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION**

**SCOTTSDALE COURTHOUSE**

**Scottsdale, Arizona**

**March, April, July, August and October 1981 through February 1982**

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**U.S. DEPARTMENT OF ENERGY  
NATIONAL SOLAR DATA PROGRAM**

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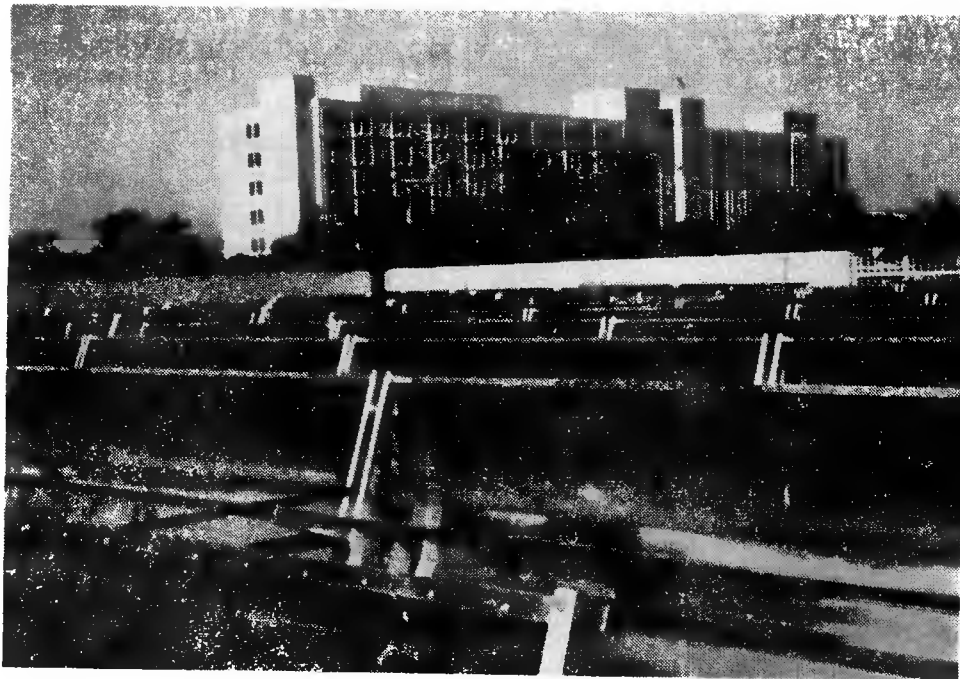
## FOREWORD

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.



SCOTTSDALE COURTHOUSE  
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SCOTTSDALE COURTHOUSE

The Scottsdale Courthouse is the County Courts Building in Scottsdale, Arizona. The active solar energy system is designed to supply the following:

Annual Design Factors  
(Million BTU)

	<u>Total Load</u>	<u>Solar Contribution</u>	<u>% Solar</u>
Heating	47.30	47.30	100
Cooling	655.60	393.36	60

It is equipped with:

Collector: 2,723 square feet of concentrating collectors manufactured by Sun Power Systems, Inc.

Storage: 5,000 gallons of hot water storage located below grade.

Solar: 25.5-ton absorption chiller manufactured by Arkla Industries, Inc.

Auxiliary: Electric resistance heating  
25-ton electric reciprocating vapor-compressor chiller  
manufactured by Climatrol

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SECTION 1

SOLAR SYSTEM PERFORMANCE

SCOTTSDALE COURTHOUSE

MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

Solar Fraction <sup>1</sup>	5%
Solar Savings Ratio <sup>2</sup>	0.06
Conventional Fuel Savings <sup>3</sup>	1,028 kwh
Solar System COP <sup>4</sup>	2.60

Seasonal Energy Requirements

March, April, July, August, and October 1981 through February 1982  
(Million BTU)

	<u>Total Load</u>	<u>Solar Contribution</u>	<u>% Solar</u>
Heating	101.62	12.43	12
Cooling	391.96	13.11 <sup>5</sup>	3

Environmental Data

	<u>Measured Average</u>	<u>Long-Term Average</u>
Outdoor temperature	71°F	67°F
Heating degree-days (Total)	941	1,552
Cooling degree-days (Total)	2,524	2,001
Daily incident solar energy	1,403 BTU/ft <sup>2</sup>	1,667 BTU/ft <sup>2</sup>

- Solar Fraction =  $\frac{\text{Solar Contribution}}{\text{Total Load}} \times 100$
- Solar Savings Ratio =  $\frac{\text{Solar Energy Supplied to Load} - \text{Solar System Operating Energy}}{\text{Total Load}}$
- Conventional Fuel Savings = Savings in BTU x  $292.8 \times 10^{-6}$  kwh/BTU
- Solar System COP =  $\frac{\text{Solar Energy Used}}{\text{Solar-Unique Operating Energy}}$
- Space cooling provided by solar equipment.

## 1.1 SUMMARY AND CONCLUSIONS

The Scottsdale Courthouse solar energy system performed well below design expectations during the period March 1981 through February 1982 excluding May, June, and September 1981. During these nine months, the solar energy system supplied only five percent of the total system load. The solar energy system was designed to provide 100% of the space heating load and 60% of the space cooling load. The system thermal performance is summarized in Table 1 and shown graphically in Figure 1. The seasonal flow of energies through the system is shown in Figure 2.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU, unless otherwise indicated)

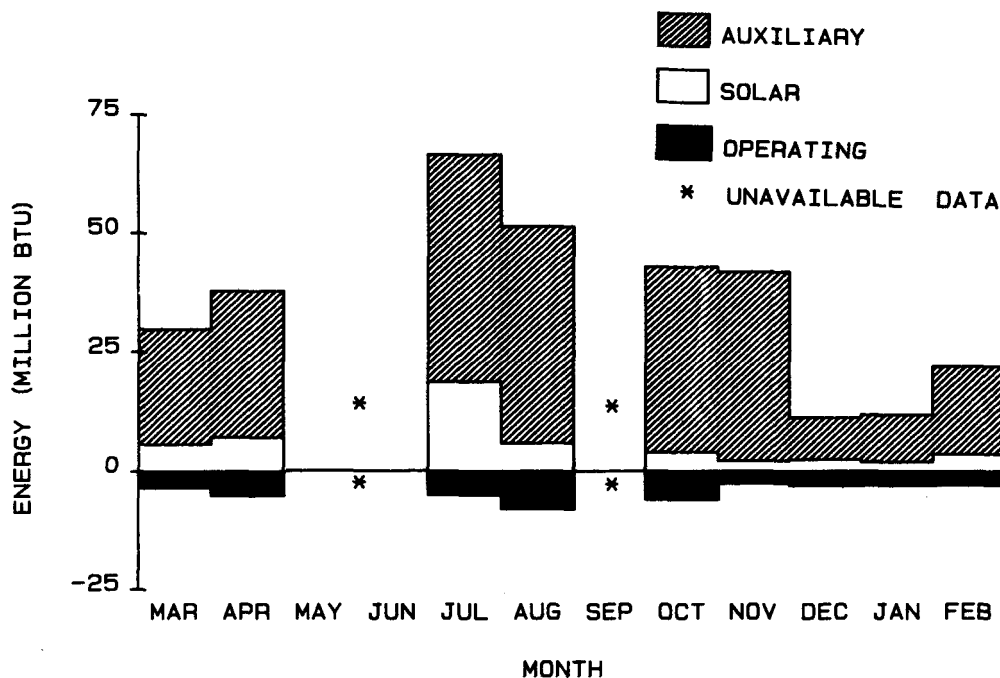
MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY ELECTRICAL	OPERATING ENERGY	ENERGY SAVINGS ELECTRICAL	SOLAR FRACTION (%)
MAR	10.03	42.04	5.65	27.59	3.43	3.61	11
APR	I	41.29	7.09	41.59	5.04	-0.05	6
JUL	19.47	103.17	18.71	67.92	4.93	3.25	6
AUG	I	96.77	5.85	64.50	7.88	-4.14	2
OCT	5.93	77.07	3.93	49.20	5.96	-3.20	2
NOV	-2.05	69.78	2.15	46.88	2.59	-0.53	1
DEC	5.82	11.28	2.43	8.81	3.08	1.29	14
JAN	5.15	12.72	1.93	10.21	3.01	0.83	10
FEB	7.34	39.46	3.59	21.76	2.93	2.45	9
TOTAL	*	493.58	51.33	338.46	38.85	3.51	-
AVERAGE	*	54.84	5.70	37.61	4.32	0.39	5

I Denotes invalid data.

\* Denotes meaningful sum is not available.

The system used 338.46 million BTU of auxiliary electric energy and 51.33 million BTU of solar energy to provide for a system load of 493.58 million BTU. Delivery of the energies required 38.85 million BTU of operating energy.

During these nine months, the solar energy system provided an electrical energy savings of only 3.51 million BTU. This is equivalent to 1,028 kwh or approximately \$66.00 based on a national average fuel cost of 6.42 cents per kwh.



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  
 Scottsdale Courthouse  
 March, April, July, August, and October 1981 through February 1982

The solar energy Coefficient of Performance (COP) is shown in Table 2. The COP simply provides a numerical value for the relationship of solar energy used or collected, and the operating energy required to collect or deliver it. The greater the COP, the more efficient the system. The solar energy system COP for the total period was 2.60. The collector subsystem was able to operate with an average COP of 14.44. The average solar cooling and solar heating COPs were 3.14 and 5.84 respectively.

The poor performance of the solar energy system is a result of the extremely poor performance of the collector array. The collector subsystem performance is summarized in Table 3.

The collector array was able to collect only seven percent of the total available insolation and nine percent of the insolation available when the collector pump was operational. (The total energy collected during the reporting period could not be computed because of unavailable data during April and August.) Operation of the collector pump and collector controls required 5.09 million BTU of operating energy. The collector array was exposed to 1,052.53 million BTU of solar energy during the nine-month period.

The primary reason for poor collector performance was the inability to properly track the incoming beam radiation. The collector pump often operated with excellent available insolation but with a small positive or negative temperature difference across the collector array. Visual inspection of the tracking equipment indicated excessive free play in the collector rotation.

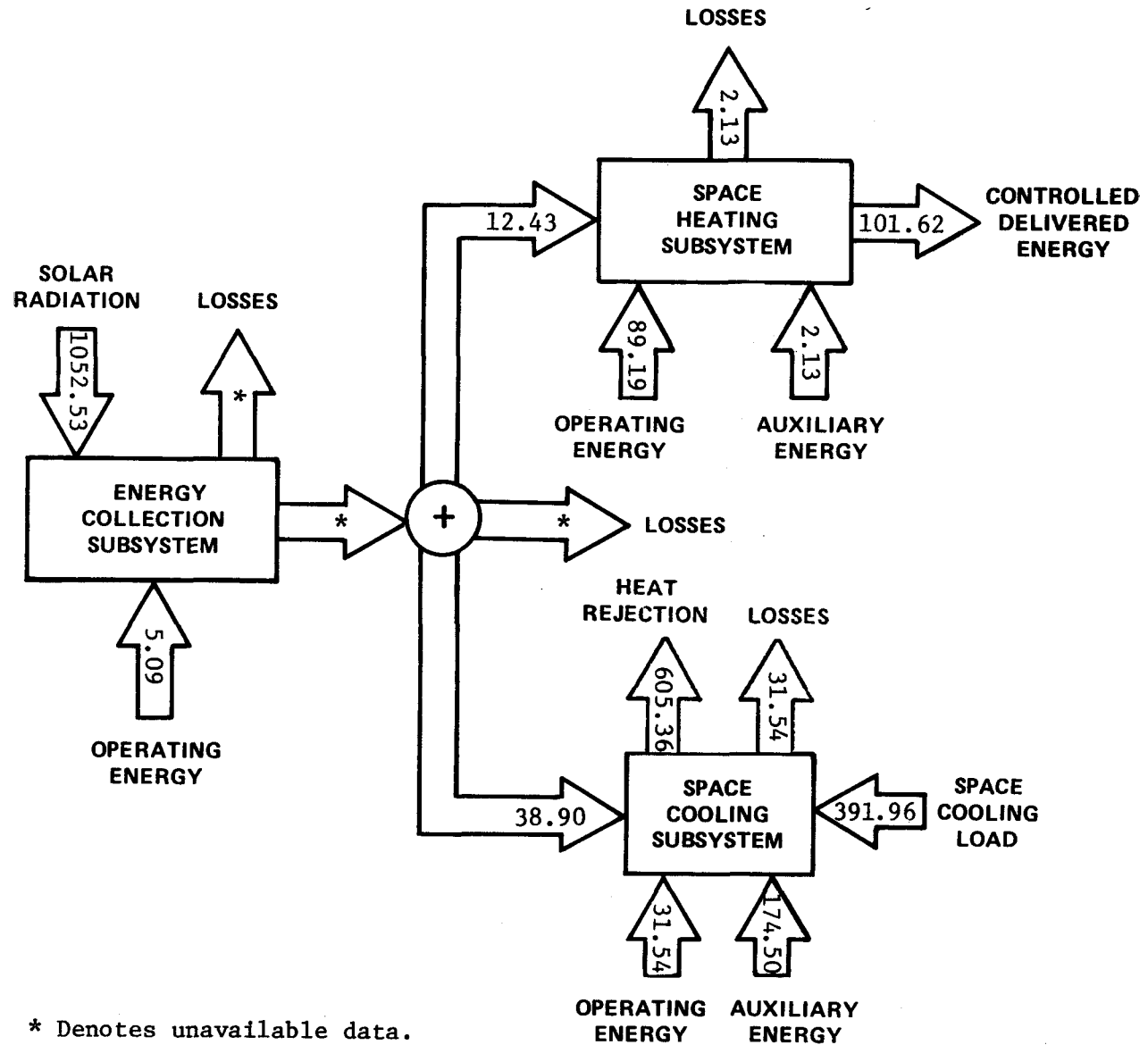


Figure 2. Energy Flow Diagram for Scottsdale Courthouse  
 March, April, July, August, and October 1981 through February 1982  
 (Figures in million BTU)

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	SPACE HEATING SOLAR	SPACE COOLING SOLAR
MAR	6.01	16.72	33.77	6.00
APR	2.71	I	-	4.40
JUL	7.51	27.06	-	10.57
AUG	1.04	I	-	1.14
OCT	1.01	9.88	-	1.23
NOV	2.76	-5.26	0.74	10.05
DEC	2.13	13.86	3.86	-
JAN	1.75	11.44	3.45	-
FEB	3.23	18.35	5.71	0.56
AVERAGE	2.60	14.44	5.84	3.14

I Denotes invalid data.

Table 3. COLLECTOR SUBSYSTEM PERFORMANCE

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 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	DAYTIME AMBIENT TEMPERATURE (°F)
MAR	127.84	10.03	8	97.28	10	0.60	71
APR	164.86	I	I	157.32	I	1.01	73
JUL	178.98	19.48	11	132.86	15	0.72	103
AUG	165.97	I	I	I	I	0.50	107
OCT	111.62	5.93	5	94.29	6	0.60	82
NOV	79.19	-2.05	-3	71.64	-3	0.39	76
DEC	70.82	5.82	8	62.98	9	0.42	68
JAN	68.97	5.15	8	62.41	8	0.45	61
FEB	84.28	7.34	9	69.30	10	0.40	68
TOTAL	1,052.53	*	-	*	-	5.09	-
AVERAGE	116.95	*	7(1)	*	9(1)	0.57	79

I Denotes invalid data.

\* Denotes meaningful sum is not available.

(1) Does not include April or August data.

mechanisms. It was also noted that one of the four banks of collectors often would remain in the stowed position when the other three banks were being focused.

Collector pump operation was erratic throughout much of the reporting period. During the first nine days in March 1981, the pump was inoperable due to the failure of the motor starter. Throughout the period, there were many unexplained instances when the collector pump would shut down during high insolation periods. There were also bright, sunny days when the collector pump did not start up at all. These problems degraded collector performance.

Prior to this reporting period, a tinted film was placed over the photocell sensor which activated the collector pump. The pump had been activating with only the slightest levels of light. With the addition of the film, the pump was usually activated at approximately 70 BTU/ft<sup>2</sup>-hr and shut down at 30 BTU/ft<sup>2</sup>-hr. However, even at these insolation levels, the collector array usually lost energy for the first and last hours of daily collection. Had the tracking mechanism been working properly, the above insolation levels might have been adequate control points.

Control of the collector pump with the photocell sensor also caused poor performance when the insolation was largely diffuse. The collector pump is started at the set light level but the concentrating collectors were unable to collect the diffuse sunlight so the collector operated at low or negative efficiencies.

The major load at Scottsdale Courthouse during the reporting period was the space cooling load. The solar energy system was designed to provide 60% of a projected annual cooling load of 655.60 million BTU. The projected cooling load for the nine reporting months was 425.30 million BTU. The measured cooling load for the period was 391.96 million BTU of which three percent was supplied by the solar-fired absorption chiller. The performance of the space cooling system is shown in Table 4.

The space cooling subsystem used 38.90 million BTU of solar energy and 249.27 million BTU of auxiliary electric energy to meet the cooling demand. The system required 31.54 million BTU of operating energy. The building temperature was maintained at an average 77°F.

A solar-fired absorption chiller and an electric reciprocating chiller are used to meet the cooling demand. The performance summary for both chillers is contained in Table 5.

The absorption chiller provided 13.11 million BTU of space cooling using 38.90 million BTU of solar energy. The average Coefficient of Performance (COP) for the reporting period was 0.34. The COP is the ratio of space cooling provided to solar energy used. The performance of the chiller was severely hindered by the poor performance of the collector array. The array was simply not able to supply the chiller with the solar energy needed for continuous operation; a key factor for high chiller COPs.

Table 4. SPACE COOLING SUBSYSTEM

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU, unless otherwise indicated)

MONTH	COOLING LOAD	SOLAR		OPER ENERGY	AUX THERMAL USED	AUX ELECT FUEL	BUILDING TEMP (°F)	COOLING DEGREE- DAYS
		FRACTION OF LOAD (%)	SOLAR ENERGY USED					
MAR	21.70	1	1.26	2.70	8.15	11.64	74	27
APR	35.91	6	7.09	4.03	25.35	36.21	79	281
JUL	102.41	6	18.71	4.21	47.02	67.16	85	910
AUG	95.63	2	5.85	7.38	44.35	63.36	86	961
OCT	62.13	6	3.93	5.27	23.98	34.26	79	236
NOV	46.82	1	2.01	2.01	16.84	24.06	75	84
DEC	0.12	0	0.00	2.03	0.06	0.08	73	3
JAN	1.69	0	0.00	2.00	0.78	1.11	72	0
FEB	25.55	0	0.05	1.91	7.97	11.39	74	22
TOTAL	391.96	-	38.90	31.54	174.50	249.27	-	2,524
AVERAGE	43.55	3	4.32	3.50	19.39	27.70	77	280

Table 5. CHILLER PERFORMANCE

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR CHILLER			AUXILIARY CHILLER		
	EQUIPMENT LOAD	THERMAL ENERGY INPUT	COEFFICIENT OF PERFORMANCE (COP)	EQUIPMENT LOAD	THERMAL ENERGY INPUT	COEFFICIENT OF PERFORMANCE (COP)
MAR	0.29	1.26	0.23	21.41	8.15	1.84
APR	2.36	7.09	0.33	33.55	25.35	0.93
JUL	7.18	18.71	0.38	95.23	47.02	1.42
AUG	1.82	5.85	0.31	93.81	44.35	1.48
OCT	1.24	3.93	0.32	60.89	23.98	1.78
NOV	0.21	2.01	0.10	46.61	16.84	1.94
DEC	0.00	0.00	-	0.12	0.06	1.50
JAN	0.00	0.00	-	1.69	0.78	1.52
FEB	0.01	0.05	0.20	25.54	7.97	2.24
TOTAL	13.11	38.90	-	378.85	174.50	-
AVERAGE	1.46	4.32	0.34	42.09	19.39	1.52

In order to supply 60% of the space cooling load, the absorption chiller, operating at a reasonable COP of 0.55, would have required 427.59 million BTU of solar energy. That would amount to 41% of the total energy incident on the collector array. This amount indicates that the design value of a 60% solar fraction is optimistic because of piping losses, storage losses, and normal collector inefficiencies, and because solar demands of another load subsystem must be accounted for.

The auxiliary electric chiller provided 378.85 million BTU of space cooling using 249.27 million BTU of electrical energy or 174.50 million BTU of auxiliary thermal energy; the equivalent electrical energy turned into useful work. The chiller operated at an average electrical COP of 1.52 which is somewhat low for an electric chiller. This COP is the ratio of space cooling provided to electrical energy consumed.

The performance of the space heating system is summarized in Table 6. The space heating load for the nine months was 101.62 million BTU. Twelve percent of this load, 12.43 million BTU, was supplied by the solar energy system. The remainder of the load was met with 89.19 million BTU of auxiliary electric energy. The space heating subsystem required 2.13 million BTU of operating energy to circulate solar energy to the heating coils. There were 941 heating degree-days during the reporting period.

Table 6. SPACE HEATING SUBSYSTEM

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	SOLAR FRACTION OF LOAD (%)	MEASURED SOLAR ENERGY USED	TOTAL AUXILIARY THERMAL ENERGY USED	TOTAL OPERATING ENERGY	OUTDOOR AMBIENT TEMPERATURE (°F)	BUILDING TEMPERATURE (°F)	HEATING DEGREE-DAYS
MAR	20.34	21	4.39	15.95	0.13	63	74	103
APR	5.38	0	0.00	5.38	0.00	74	79	15
JUL	0.76	0	0.00	0.76	0.00	94	85	0
AUG	1.14	0	0.00	1.14	0.00	96	86	0
OCT	14.94	0	0.00	14.94	0.00	73	79	3
NOV	22.96	1	0.14	22.82	0.19	65	75	68
DEC	11.16	22	2.43	8.73	0.63	58	73	215
JAN	11.03	17	1.93	9.10	0.56	53	72	370
FEB	13.91	25	3.54	10.37	0.62	60	74	167
TOTAL	101.62	-	12.43	89.19	2.13	-	-	941
AVERAGE	11.29	12	1.38	9.91	0.24	71	77	105

The solar energy system was intended to supply 100% of the space heating requirements. The solar fraction was only 12% because of the very poor collector performance and poor interaction of solar and auxiliary equipment. By multiplying the collector efficiency of seven percent by the 1,052.53 million BTU of incident solar energy, an approximate 74 million BTU of solar energy were collected. This amount is only 73% of the space heating load.

The interaction of the solar and auxiliary heating systems also reduced the space heating solar fraction. Flow rate through the solar heating coils in each zone is modulated based upon demand. The electric strip heaters are activated by a limit switch when the control valves are positioned wide open. This means that at full flow of solar energy, the auxiliary equipment was turned on. The problem could be remedied by placing the electric strip heaters on separate thermostats from the solar equipment and activating only when the solar equipment could not supply the demand.

The solar-specific operating energy consumed by the system is shown in Table 7. This table also shows how much solar operating energy was used by individual subsystems. The solar subsystems used a total of 19.70 million BTU of solar-specific operating energy during the reporting period. The energy collection and storage subsystem used 5.09 million BTU, the space heating subsystem used 2.13 million BTU, and the space cooling subsystem used 12.39 million BTU of solar-specific operating energy. Rejection of excess storage heat to the swimming pool required 0.09 million BTU of operating energy.

Table 7. SOLAR OPERATING ENERGY

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	SHS OPERATING ENERGY	SCS OPERATING ENERGY	TOTAL SOLAR OPERATING ENERGY
MAR	0.60	0.13	0.21	0.94
APR	1.01	0.00	1.61	2.62
JUL	0.72	0.00	1.77	2.49
AUG	0.50	0.00	5.13	5.63
OCT	0.69 <sup>(1)</sup>	0.00	3.20	3.89
NOV	0.39	0.19	0.20	0.78
DEC	0.42	0.63	0.09	1.14
JAN	0.45	0.56	0.09	1.10
FEB	0.40	0.62	0.09	1.11
TOTAL	5.18 <sup>(1)</sup>	2.13	12.39	19.70
AVERAGE	0.58	0.24	1.38	2.19

(1) Includes pool rejection pump operating energy of 0.09 million BTU.

Table 8 presents the energy savings for the solar energy system. The space heating subsystem provided an electrical savings of 10.30 million BTU. The solar cooling subsystem operated at a net expense of 1.61 million BTU. This subsystem was only able to provide monthly savings in the months of April and July. During these months, the system saved 4.93 million BTU of electrical energy. The energy collection and storage subsystem along with the pool pump consumed 5.18 million BTU of operating energy which is considered an electrical expense.

Table 8. ENERGY SAVINGS

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	ECSS		NET ENERGY SAVINGS ELECTRICAL	
		SPACE HEATING ELECTRICAL	SPACE COOLING ELECTRICAL		
MAR	5.65	4.26	-0.05	-0.60	3.61
APR	7.09	0.00	0.96	-1.01	-0.05
JUL	18.71	0.00	3.97	-0.72	3.25
AUG	5.85	0.00	-3.64	-0.50	-4.14
OCT	3.93	0.00	-2.51	-0.69 <sup>(1)</sup>	-3.20
NOV	2.15	-0.05	-0.09	-0.39	-0.53
DEC	2.43	1.80	-0.09	-0.42	1.29
JAN	1.93	1.37	-0.09	-0.45	0.83
FEB	3.59	2.92	-0.07	-0.40	2.45
TOTAL	*51.33	10.30	-1.61	-5.18 <sup>(1)</sup>	3.51
AVERAGE	5.70	1.14	-0.18	-0.58	0.39

<sup>(1)</sup>Includes pool rejection pump expense of 0.09 million BTU.

The net system electrical savings for the nine-month period were 3.51 million BTU. As mentioned earlier, this is a savings of approximately \$66.00, or \$5.50 per month. This retrofit solar system cost an approximate \$355,000.00.

The measured and long-term weather conditions are summarized in Table 9. The average available insolation was 1,403 BTU/ft<sup>2</sup>-day versus the long-term average of 1,667 BTU/ft<sup>2</sup>-day. The average ambient temperature was 71°F and the long-term average temperature was 67°F. During these nine months, there were 941 heating degree-days and 2,524 cooling degree-days. During the same months, there were 1,552 long-term average heating degree-days and 2,001 long-term average cooling degree-days.

Table 9. WEATHER CONDITIONS

SCOTTSDALE COURTHOUSE  
MARCH, APRIL, JULY, AUGUST, AND OCTOBER 1981 THROUGH FEBRUARY 1982

MONTH	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT <sup>2</sup> -DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
MAR	1,509	1,814	63	60	103	185	27	21
APR	2,011	2,356	74	68	15	60	281	141
JUL	2,113	2,485	94	91	0	0	910	812
AUG	1,959	2,293	96	89	0	0	961	747
OCT	1,317	1,578	73	72	3	17	236	240
NOV	966	1,150	65	60	68	182	84	26
DEC	836	933	58	53	215	388	3	0
JAN	814	1,021	53	51	370	428	0	0
FEB	1,101	1,372	60	55	167	292	22	14
TOTAL	-	-	-	-	941	1,552	2,524	2,001
AVERAGE	1,403	1,667	71	67	105	172	280	222

## 1.2 SYSTEM OPERATION

### 1.2.1 TYPICAL SYSTEM OPERATION

Typical system operation on a clear bright day (July 10, 1981) is shown graphically in Figures 3a, 3b, and 3c. Figure 3a portrays the insolation on the collector array plotted against time of day. It also shows the period of time when the collector pump was operating. On this particular day, the collector pump operated continuously from 0723 hours to 1900 hours. At the shutoff point, 1900 hours, the insolation level was so low that the collector array was actually losing energy from storage.

Figure 3b portrays the collector inlet and outlet temperatures. As the insolation heated the absorber tube in the early morning, the collector outlet temperature can be seen rising rapidly. At 0723 hours, the collector pump was activated and the collector temperatures leveled off. Large fluxuations in collector temperature can be seen between 0800 hours and 1015 hours because of the solar absorption chiller cycling on and off. At 1708 hours, the collector outlet temperature dropped below the inlet temperature because of low insolation. The system operated with a negative efficiency until the collector pump shut down at 1900 hours.

The inside ambient temperature is shown in Figure 3c. At 0416 hours, the auxiliary electric chiller was activated and cooled the space temperature sharply. At 0848 hours, the solar absorption chiller was started which helped to further reduce the space temperature. At 1616 hours and 2025 hours, the absorption chiller and electric chiller were shut down. The effect is seen on the plot as sharp rises in the space temperature.

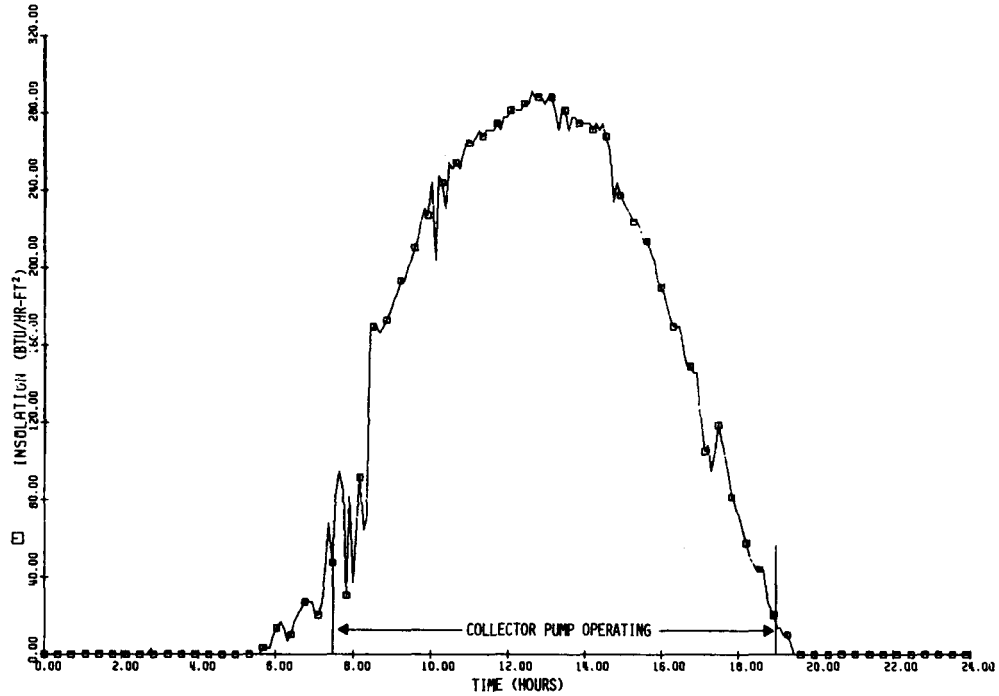


Figure 3a. Typical Insolation Data  
 Scottsdale Courthouse  
 July 10, 1981

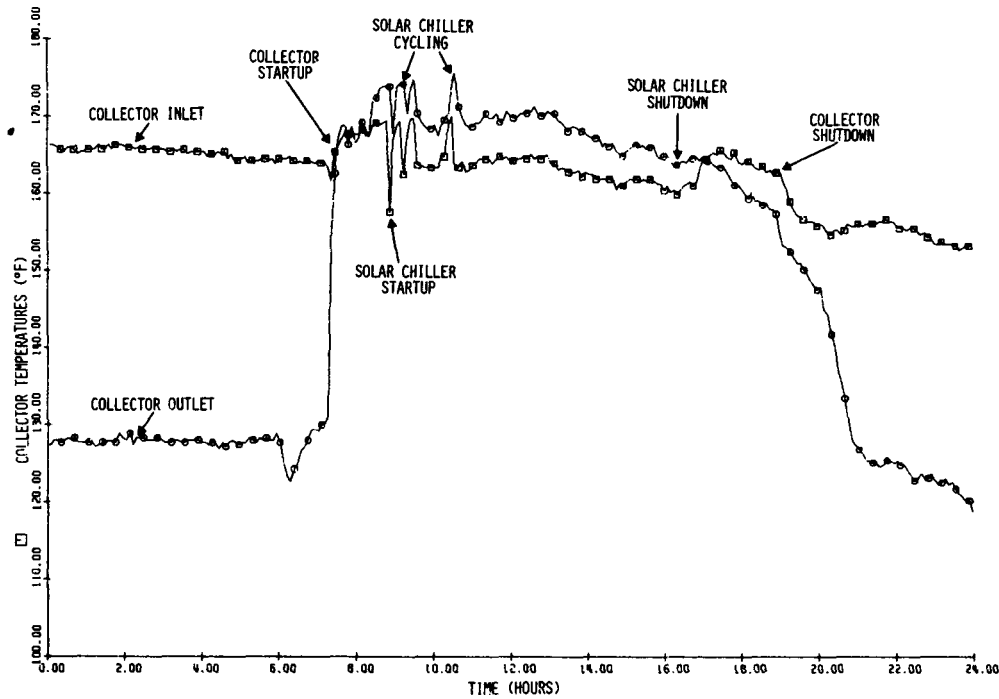


Figure 3b. Typical Collector Array Temperatures, Inlet/Outlet  
 Scottsdale Courthouse  
 July 10, 1981

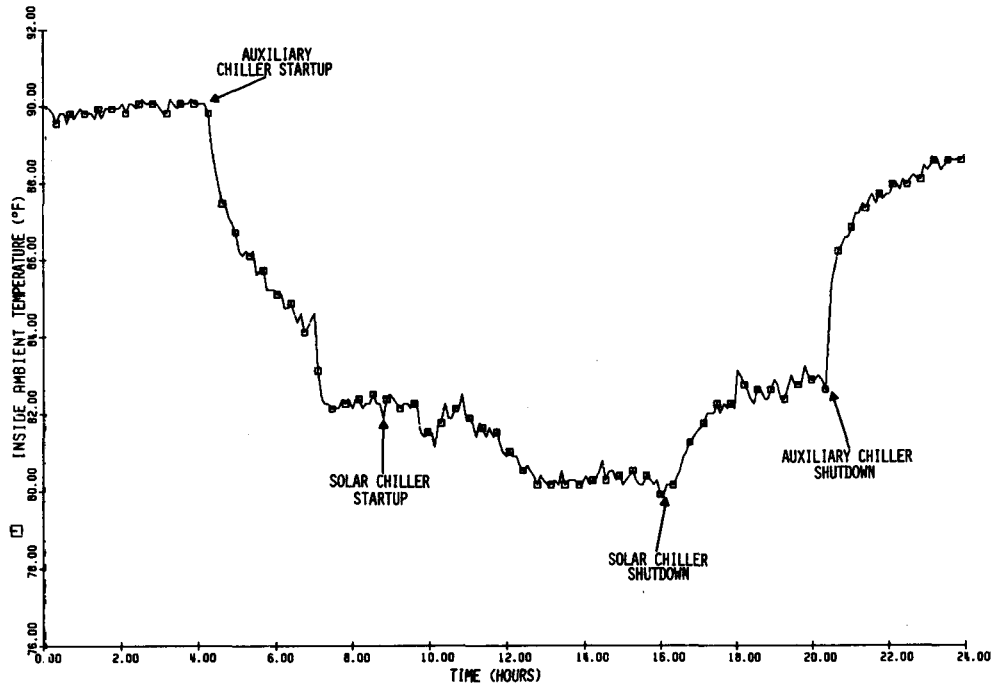


Figure 3c. Typical Building Ambient Temperature  
Scottsdale Courthouse  
July 10, 1981

### 1.2.2 SYSTEM OPERATING SEQUENCE

The bar chart in Figure 4 shows the system operating sequence for July 10, 1981. This data correlates with the curves presented in Figures 3a, 3b, and 3c. This chart shows the interaction of the collector subsystem with the storage tank and absorption chiller. When the absorption chiller is not operational, the collector is used to heat the storage tank. When the absorption chiller is operating, solar heated water is drawn from storage and pumped from the collectors to provide the chiller with energy.

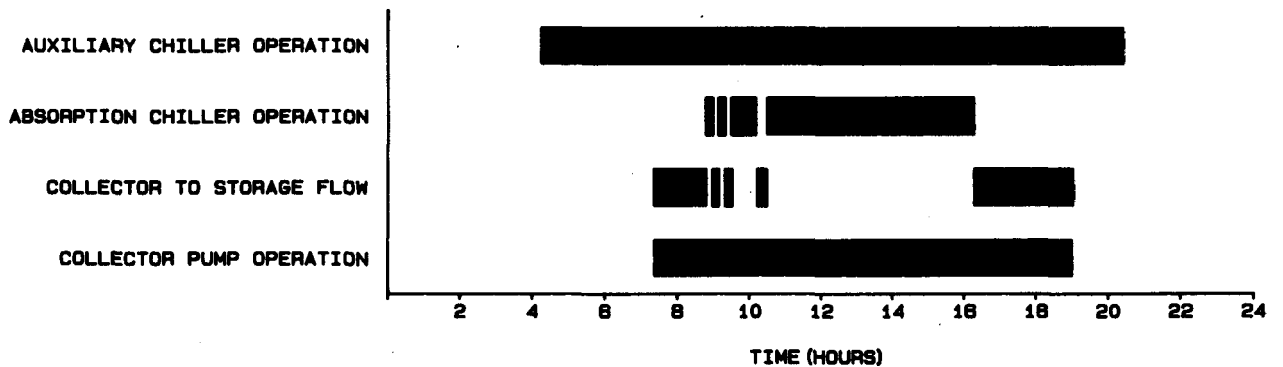


Figure 4. Typical Operating Sequence  
Scottsdale Courthouse  
July 10, 1981

## SECTION 2

### REFERENCES

- \*1. National Solar Data Network, Department of Energy, prepared under Contract Number DE-AC01-79CS30027, Vitro Laboratories, Silver Spring, Maryland, January 1980.
2. J. T. Smok, V. S. Sohoni, J. M. Nash, "Processing of Instrumented Data for the National Solar Heating and Cooling Demonstration Program," Conference on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, D.C., April 1978.
3. E. Streed, et al, Thermal Data Requirements and Performance Evaluation Procedures for the National Heating and Cooling Demonstration Program, NBSIR-76-1137, National Bureau of Standards, Washington, D.C., 1976.
4. 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, Scottsdale Courthouse, March 1981, Vitro Laboratories, Silver Spring, Maryland.
7. Monthly Performance Report, Scottsdale Courthouse, April 1981, Vitro Laboratories, Silver Spring, Maryland.
8. Monthly Performance Report, Scottsdale Courthouse, July 1981, Vitro Laboratories, Silver Spring, Maryland.
9. Monthly Performance Report, Scottsdale Courthouse, October 1981, Vitro Laboratories, Silver Spring, Maryland.
10. Monthly Performance Report, Scottsdale Courthouse, December 1981, Vitro Laboratories, Silver Spring, Maryland.
11. Monthly Performance Report, Scottsdale Courthouse, January 1981, Vitro Laboratories, Silver Spring, Maryland.
12. Monthly Performance Report, Scottsdale Courthouse, February 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.

APPENDIX A

SYSTEM DESCRIPTION

The Scottsdale County Courts Building is a 6,850-square-foot public office building located in Scottsdale, Arizona. The building is a single-story office building constructed of concrete block. The solar energy system is a retrofit for space cooling and heating, and is designed to provide 60% of the total cooling load and 100% of the space heating requirement. Tracking-type, concentrating collectors (2,723 square feet) are mounted horizontally in a field adjacent to the building.

The collector array is utilized to heat water which is used directly by load subsystems or stored in a 5,000-gallon, below-grade, storage tank. Hot water from the storage tank is used to provide space heating to the building through eight separate duct heating coils. The hot water also may be used to drive a 25.5-ton absorption chiller. Backup auxiliary heat for space heating is provided by a series of in-duct electric resistance strip heaters. A conventional reciprocating vapor-compression chiller provides auxiliary cooling capacity.

The system is designed to provide hot water at temperatures of up to 260°F at 12 pounds per square inch (psi). Excess thermal energy is rejected through a shell-tube heat exchanger to a swimming pool adjacent to the courthouse. The collectors are controlled by photocell-based tracking units, which also defocus the concentrating array when the collector outlet temperatures are above 260°F. A photocell system is also utilized to activate the collector subsystem, when a predetermined amount of total solar radiation is present. Freeze protection is by circulation from storage or draindown during electric failure.

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

<u>Equipment/Components</u>	<u>Manufacturer</u>	<u>Model or Description</u>
Collectors	Sun Power Systems, Inc.	Axial concentrating
Absorption Chiller	Arkla Solaire Arkla Industries, Inc.	WFB-300
Controls	Barber-Coleman, Inc.	
Pumps	Thrush Products, Inc.	

The system has several modes of operation and is shown schematically in Figure A-1.

Mode 1 - Collector-to-Storage - This mode is entered when 75 BTU/ft<sup>2</sup>-hr of solar radiation are available, storage temperature is less than 250°F, and no solar load subsystems are activated. Pump P1 is activated, valve V1 is opened, and the collector tracking control units focus the collectors toward the sun. This mode continues until collector outlet temperatures reach 260°F,

a demand subsystem activates, or solar radiation becomes unavailable. A demand subsystem may activate and thus switch the mode. The collectors may still operate during this mode switch.

Mode 2 - Collector-to-Cooling - This mode is entered when the collector subsystem is activated and a demand for mechanical refrigeration exists. The absorption chiller is energized, pump P2 is activated to draw a percentage of the collector hot water return flow to the heated side of the chiller. Pumps P3, P4, the air handling unit, and the chilled water recirculation pump are activated. Modulating valve V4 regulates the hot water flow rate through the absorption chiller to maintain a 45°F outlet temperature. Temperature control of the inlet stream to the chiller is achieved by modulation of valve V2, which limits the inlet temperature to 200°F. The cooling tower loop flow is modulated through the action of valve V5 to maintain an 85°F condensor temperature. This mode ceases when cooling demand is satisfied, or when the inlet temperature to the chiller falls below 160°F.

Mode 3 - Collector-to-Heating - This mode is activated when the collector subsystem is activated, no cooling demand exists, and there is a demand for heating in any of the building's control zones. The hot water circulation pump, P5, is activated whenever the outside ambient temperature is below 65°F, and collected energy is available. The air handling unit is also activated. Modulating valve V3 varies the proportion of hot water supply and return flows from the heating coils and thus varies the hot water temperature according to the outside temperature. The hot water is circulated to a series of eight hydronic heating coils mounted in the multizone air handling unit. Modulating valves at each of the eight coils vary the hot water flow according to one of eight zone thermostats, each of which controls a heating coil. If the hydronic coils do not meet the zone thermostatic control requirements, a limit switch at the individual control valves activates one or more of the resistance heaters located in the air handling system. Auxiliary heating thus may occur simultaneously with this mode. If the auxiliary heating only is active, this is considered to be mode 5A.

Mode 4 - Storage-to-Cooling - This mode is entered when temperature levels in the building require cooling, no collection is occurring, and the storage temperature is greater than 180°F. The control sequences for the chiller operating in mode 4 are similar to mode 2, except that the hot water supply is from storage only, rather than directly from the collector field. This mode ceases when cooling demand is satisfied, or when the chiller inlet temperature falls below 160°F.

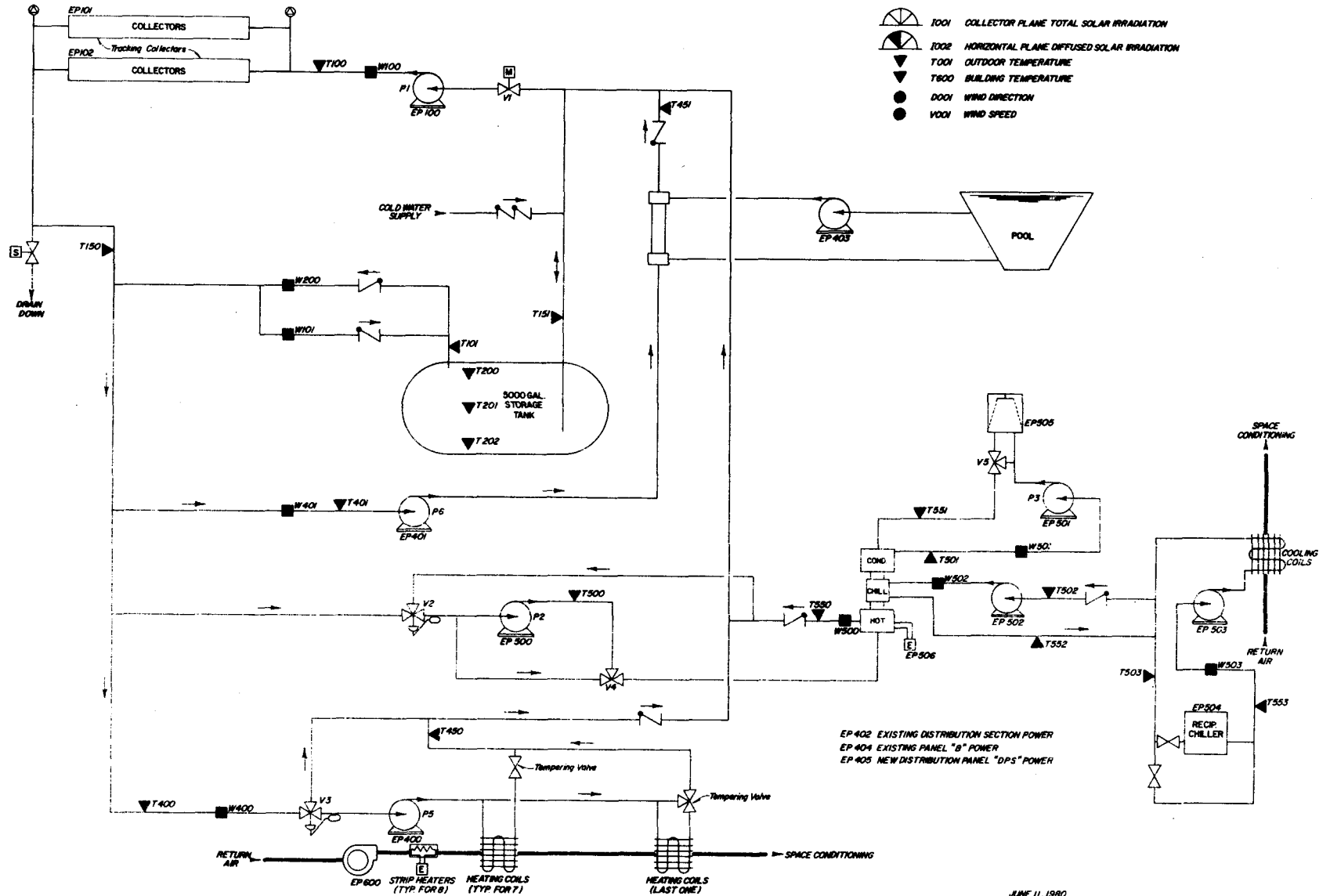
Mode 5A, 5B - Storage-to-Heating - Mode 5A occurs when a heating demand exists in one or more zones, collection is not occurring, and the storage temperature averages 100°F or more. Mode 5B occurs when storage is below 100°F, and auxiliary electric heating only occurs.

The control logic of this mode is similar to that of mode 3, except that the hot water is supplied directly from storage and not from the collection loop. Auxiliary electric heating also occurs simultaneously with this mode.

Mode 6 - Auxiliary Cooling - If there is no collected solar energy available either directly or from storage, and a cooling demand exists in any of the control zones, then the auxiliary cooling mode is entered. The 25-ton

reciprocating chiller is activated, the chilled water circulation pump is activated, and the air handling unit is activated. Auxiliary cooling proceeds until cooling demand is satisfied, or solar cooling becomes available. Modes 2 and 4 are interlocked so that no solar cooling occurs when the reciprocating unit is operating, and vice versa.

Mode 7A, 7B - Energy Rejection - Mode 7A is entered when the pool temperature is below 85°F and excess temperature (above 250°F) is available from the collector subsystem. Mode 7B is similar except flow is from storage only. The pool pump and pump P6 are activated until energy is no longer available from collector or storage.



JUNE 11, 1980

Figure A-1. Scottsdale Courthouse Solar Energy System Schematic

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

The performance of the Scottsdale Courthouse 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.

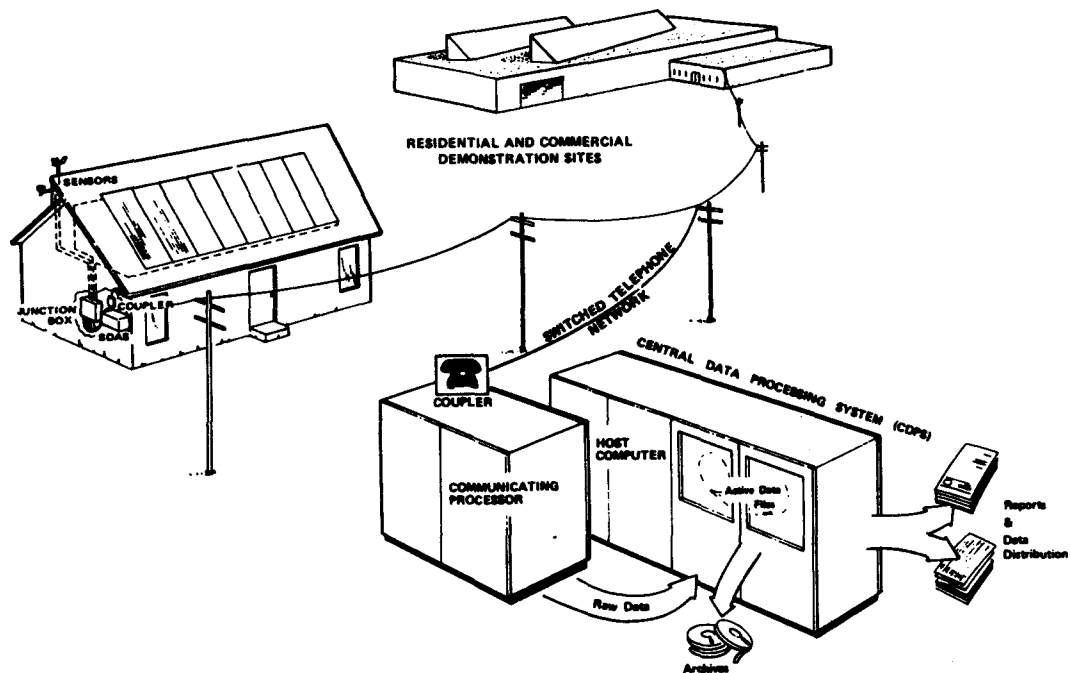


Figure B-1. The National Solar Data Network

## 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 Scottsdale Courthouse solar energy system for March, April, July, August, and October 1981 through February 1982 was analyzed and Monthly Performance Reports were written for months when sufficient valid data were available. See the following page for a list of these reports.

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

OTHER DATA REPORTS ON THIS SITE

Monthly Performance Reports:

\*October 1980, SOLAR/2055-80/10  
\*November 1980, SOLAR/2055-80/11  
\*December 1980, SOLAR/2055-80/12  
February 1981  
March 1981  
April 1981  
July 1981  
October 1981  
December 1981  
January 1982  
February 1982

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

## APPENDIX C

### PERFORMANCE FACTORS AND SOLAR TERMS

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

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

Section 3 describes general acronyms used in this report.

- Section 1. Performance Factor Definitions and Acronyms
- Section 2. Solar Terminology
- Section 3. General Acronyms

SECTION 1. PERFORMANCE FACTOR DEFINITIONS AND ACRONYMS

<u>ACRONYM</u>	<u>NAME</u>	<u>DEFINITION</u>
AXE	Auxiliary Electric Fuel Energy to Load Subsystem	Amount of electrical energy required as a fuel source for all load subsystems.
AXF	Auxiliary Fossil Fuel Energy to Load Subsystem	Amount of fossil energy required as a fuel source for all load subsystems.
* AXT	Auxiliary Thermal Energy to Load Subsystems	Thermal energy delivered to all load subsystems to support a portion of the subsystem loads, from all auxiliary sources.
CAE	SCS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SCS to be converted and applied to the SCS load.
CAF	SCS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SCS to be converted and applied to the SCS load.
CAREF	Collector Array Efficiency	Ratio of the collected solar energy to the incident solar energy.
CAT	SCS Auxiliary Thermal Energy	Amount of energy provided to the SCS by a BTU heat transfer fluid from an auxiliary source.
* CL	Space Cooling Subsystem Load	Energy required to satisfy the temperature control demands of the space cooling subsystem.
CLAREA	Collector Array Area	The gross area of one collector panel multiplied by the number of panels in the array.
COPE	SCS Operating Energy	Amount of energy required to support the SCS operation which is not intended to be applied directly to the SCS load.
CSAUX	Auxiliary Energy to ECSS	Amount of auxiliary energy supplied to the ECSS.
* CSCEF	ECSS Solar Conversion Efficiency	Ratio of the solar energy supplied from the ECSS to the load subsystems to the incident solar energy on the collector array.

\* Primary Performance Factors

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

\* Primary Performance Factors

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

\* Primary Performance Factors

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

\* Primary Performance Factors

<u>ACRONYM</u>	<u>NAME</u>	<u>DEFINITION</u>
* SEL	Solar Energy to Load Subsystems	Amount of solar energy supplied by the ECSS to all load subsystems.
* SFR	Solar Fraction of System Load	Portion of the system load which was supported by solar energy.
STECH	Change in ECSS Stored Energy	Change in ECSS stored energy during reference time period.
STEFF	ECSS Storage Efficiency	Ratio of the sum of energy supplied by ECSS storage and the change in ECSS stored energy to the energy delivered to the ECSS storage.
STEI	Energy Delivered to ECSS Storage	Amount of energy delivered to ECSS storage by the collector array and from auxiliary sources.
STEO	Energy Supplied by ECSS Storage	Amount of energy supplied by ECSS storage to the load subsystems.
* SYSL	System Load	Energy required to satisfy all desired temperature control demands at the output of all subsystems.
* SYSOPE	System Operating Energy	Amount of energy required to support the system operation, including all subsystems, which is not intended to be applied directly to the system load.
* SYSPF	System Performance Factor	Ratio of the system load to the total equivalent fossil energy expended or required to support the system load.
* TA	Ambient Temperature	Average temperature of the ambient air.
* TB	Building Temperature	Average temperature of the controlled space of the building.
TCECOP	TCE Coefficient of Performance	Coefficient of performance of the thermodynamic conversion equipment.
TCEI	TCE Thermal Input Energy	Equivalent thermal energy which is supplied as a fuel source to thermodynamic conversion equipment.

\* Primary Performance Factors

<u>ACRONYM</u>	<u>NAME</u>	<u>DEFINITION</u>
TCEL	Thermodynamic Conversion Equipment Load	Controlled energy output of thermodynamic conversion equipment.
TCEOPE	TCE Operating Energy	Amount of energy required to support the operation of thermodynamic conversion equipment which is not intended to appear directly in the load.
TCERJE	TCE Reject Energy	Amount of energy intentionally rejected or dumped from thermodynamic conversion equipment as a by-product or consequence of its principal operation.
TDA	Daytime Average Ambient Temperature	Average temperature of the ambient air during the daytime (during normal collector operation period).
* TECSM	Total Energy Consumed by System	Amount of energy demand of the system from external sources; sum of all fuels, operating energies, and collected solar energy.
THW	Service Hot Water Temperature	Average temperature of the service hot water supplied by the system.
TST	ECSS Storage Temperature	Average temperature of the ECSS storage medium.
* TSVE	Total Electrical Energy Savings	Difference in the estimated electrical energy required to support an assumed similar conventional system and the actual electrical energy required to support the system, for identical loads; sum of electrical energy savings for all subsystems.
* TSVF	Total Fossil Energy Savings	Difference in the estimated fossil energy required to support an assumed similar conventional system and the actual fossil energy required to support the system, for identical loads; sum of fossil energy savings of all subsystems.
TSW	Supply Water Temperature	Average temperature of the supply water to the hot water subsystem.

\* Primary Performance Factors

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

\* Primary Performance Factors

## SECTION 2. SOLAR TERMINOLOGY

<b>Absorptivity</b>	The ratio of absorbed radiation by a surface to the total incident radiated energy on that surface.
<b>Active Solar System</b>	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.
<b>Air Conditioning</b>	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.
<b>Ambient Temperature</b>	The surrounding air temperature.
<b>Auxiliary Energy</b>	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.
<b>Auxiliary Energy Subsystem</b>	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.
<b>Array</b>	An assembly of a number of collector elements, or panels, into the solar collector for a solar energy system.
<b>Backflow</b>	Reverse flow.
<b>Backflow Preventer</b>	A valve or damper installed to prevent reverse flow.
<b>Beam Radiation</b>	Radiated energy received directly, not from scattering or reflecting sources.
<b>Collected Solar Energy</b>	The thermal energy added to the heat transfer fluid by the solar collector.

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

<b>Heat Exchanger</b>	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.
<b>Heat Transfer Fluid</b>	The fluid circulated through a heat source (solar collector) or heat exchanger that transports the thermal energy by virtue of its temperature.
<b>Heating Degree-Days</b>	The sum over a specified period of time of the number of degrees the average daily temperature is <u>below</u> 65°F.
<b>Instantaneous Efficiency</b>	The efficiency of a solar collector at one operating point, $\frac{T_i - T_a}{I}$ , under steady state conditions (see Operating Point).
<b>Instantaneous Efficiency Curve</b>	A plot of solar collector efficiency against operating point, $\frac{T_i - T_a}{I}$ (see Operating Point).
<b>Incidence Angle</b>	The angle between the line to a radiating source (the sun) and a line normal to the plane of the surface being irradiated.
<b>Incident Solar Energy</b>	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.
<b>Insolation</b>	Incoming solar radiation.
<b>Load</b>	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.
<b>Manifold</b>	The piping that distributes the transport fluid to and from the individual panels of a collector array.
<b>Microclimate</b>	Highly localized weather features which may differ from long-term regional values due to the interaction of the local surface with the atmosphere.

Nocturnal Radiation	The loss of thermal energy by the solar collector to the night sky.
Operating Energy	The amount of energy (usually electrical energy) required to operate the solar and auxiliary equipments and to transport the thermal energy to the point of use, and which is not intended to directly affect the thermal state of the system.
Operating Point	A solar energy system has a dynamic operating range due to changes in level of insolation (I), fluid input temperature (T), and outside ambient temperature (Ta). The operating point is defined as:
	$\frac{T_i - T_a}{I} \quad \left( \frac{^{\circ}\text{F} \times \text{hr.} \times \text{sq. ft.}}{\text{BTU}} \right)$
Operational Collector Efficiency	Ratio of collected solar energy to incident solar energy <u>only during the time the collector fluid is being circulated with the intention of delivering solar-source energy to the system.</u>
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 Fraction	The fraction of the total load supplied by solar energy. The ratio of solar energy supplied to loads divided by total load. Often expressed as a percentage.
Solar Savings Ratio	The ratio of the solar energy supplied to the load minus the solar system operating energy, divided by the system load.
Storage Efficiency, $N_s$	Measure of effectiveness of transfer of energy through the storage subsystem taking into account system losses.
Storage Subsystem	The assembly of components used to store solar-source energy for use during periods of low insolation.
Stratification	A phenomenon that causes a distinct thermal gradient in a heat transfer fluid, in contrast to a thermally homogeneous fluid. Results in the layering of the heat transfer fluid, with each layer at a different temperature. In solar energy systems, stratification can occur in liquid storage tanks or rock beds, and may even occur in pipes and ducts. The temperature gradient or layering may occur in a horizontal, vertical or radial direction.
System Performance Factor	Ratio of system load to the total equivalent fossil energy expended or required to support the system load.
Ton of Refrigeration	The heat equivalent to the melting of one ton (2,000 pounds) of ice at 32°F in 24 hours. A ton of refrigeration will absorb 12,000 BTU/hr, or 288,000 BTU/day.
Tracking Collector	A solar collector that moves to point in the direction of the sun.
Zone	A portion of a conditioned space that is controlled to meet heating or cooling requirements separately from the other space or other zones.

### SECTION 3. GENERAL ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineering.
BTU	British Thermal Unit, a measure of heat energy. The quantity of heat required to raise the temperature of one pound of pure water one Fahrenheit degree. One BTU is equivalent to $2.932 \times 10^{-4}$ 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  
SCOTTSDALE COURTHOUSE

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

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

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,  $\Delta t$  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

$$\text{COLLECTED SOLAR ENERGY} = \sum [M100 \times \Delta H] \times \Delta t$$

where M100 is the mass flow rate of the heat transfer fluid in  $\text{lb}_m/\text{min}$  and  $\Delta H$  is the enthalpy change, in  $\text{BTU}/\text{lb}_m$ , of the fluid as it passes through the heat exchanging component.

For a liquid system  $\Delta H$  is generally given by

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

where  $\bar{C}_p$  is the average specific heat, in  $\text{BTU}/\text{lb}_m\text{-}^\circ\text{F}$ , of the heat transfer fluid and  $\Delta T$ , in  $^\circ\text{F}$ , is the temperature differential across the heat exchanging component.

\* See Appendix B.

For an air system  $\Delta H$  is generally given by

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

where  $H_a(T)$  is the enthalpy, in BTU/lb<sub>m</sub>, 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
WI	=	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

AVERAGE AMBIENT TEMPERATURE (°F)

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

US WEATHER STATION AVERAGE AMBIENT TEMPERATURE (°F)

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

HEATING DEGREE-DAYS/COOLING DEGREE-DAYS

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

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

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

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

AVERAGE BUILDING TEMPERATURE (°F)

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

DAYTIME AVERAGE AMBIENT TEMPERATURE (°F)

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

for ± three hours from solar noon

INCIDENT SOLAR ENERGY PER SQUARE FOOT (BTU/FT<sup>2</sup>)

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

OPERATIONAL INCIDENT SOLAR ENERGY (BTU)

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

when the collector loop is active

SOLAR ENERGY COLLECTED BY THE ARRAY (BTU)

$$SECA = \Sigma M100 \times HWD (T150, T100) \times \Delta\tau$$

INCIDENT SOLAR ENERGY ON COLLECTOR ARRAY (BTU)

$$SEA = CLAREA \times SE$$

COLLECTED SOLAR ENERGY (BTU/FT<sup>2</sup>)

$$SEC = SECA/CLAREA$$

COLLECTOR ARRAY EFFICIENCY

$$CLEF = SECA/SEA$$

OPERATIONAL COLLECTOR ARRAY EFFICIENCY

$$CLEFOP = SECA/SEOP$$

ECSS OPERATING ENERGY (BTU)

$$CSOPE = 56.8833 \times \Sigma EP100 \times \Delta\tau$$

SPACE HEATING SUBSYSTEM

SOLAR ENERGY TO SPACE HEATING (BTU)

$$HSE = \Sigma M400 \times HWD (T400, T450) \times \Delta\tau$$

SPACE HEATING AUXILIARY ELECTRIC ENERGY (BTU)

$$HAE = 56.8833 \times \Sigma EP444 \times \Delta\tau$$

SPACE HEATING AUXILIARY THERMAL ENERGY (BTU)

$$\text{HAT} = \text{HAE}$$

CONTROLLED DELIVERED ENERGY (BTU)

$$\text{CDE} = \text{HAT} + \text{HSE}$$

SOLAR SPECIFIC SPACE HEATING OPERATING ENERGY (BTU)

$$\text{HOPE1} = 56.8833 \times \Sigma \text{EP400} \times \Delta\tau$$

SPACE HEATING OPERATING ENERGY (BTU)

$$\text{HOPE} = \text{HOPE1}$$

EQUIPMENT HEATING LOAD (BTU)

$$\text{EHL} = \text{CDE}$$

HEATING SOLAR FRACTION (%)

$$\text{HSFR} = \text{HSE}/\text{EHL} \times 100\%$$

SPACE HEATING ELECTRICAL SAVINGS (BTU)

$$\text{HSVE} = \text{HSE} - \text{HOPE1}$$

THERMODYNAMIC CONVERSION EQUIPMENT (TCE)

ABSORPTION CHILLER LOAD (BTU)

$$\text{TCEL} = \Sigma \text{M502} \times \text{HWD} (\text{T502}, \text{T552}) \times \Delta\tau$$

AUXILIARY CHILLER LOAD (BTU)

$$\text{ATCEL} = \Sigma \text{M503} \times \text{HWD} (\text{T503}, \text{T553}) \times \Delta\tau$$

ABSORPTION CHILLER INPUT ENERGY (BTU)

$$\text{TCEI} = \Sigma \text{M500} \times \text{HWD} (\text{T500}, \text{T550}) \times \Delta\tau$$

AUXILIARY CHILLER INPUT ENERGY (BTU)

$$\text{ATCEI} = (56.8833 \times \Sigma \text{EP504} \times \Delta\tau) \times 0.70$$

ABSORPTION CHILLER COP

$$TCECOP = TCEL/TCEI$$

AUXILIARY CHILLER COP

$$ATCECOP = ATCEL/(ATCEI/0.70)$$

ABSORPTION CHILLER OPERATING ENERGY (BTU)

$$TCEOPE = 56.8833 \times \Sigma (EP500 + EP501 + EP502 + EP503 + EP505 + EP506) \times \Delta\tau$$

AUXILIARY CHILLER OPERATING ENERGY (BTU)

$$ATCEOPE = 56.8833 \times \Sigma EP503 \times \Delta\tau$$

SPACE COOLING SUBSYSTEM

SOLAR ENERGY TO SPACE COOLING (BTU)

$$CSE = \Sigma M500 \times HWD (T500, T550) \times \Delta\tau$$

SPACE COOLING AUXILIARY ELECTRIC ENERGY (BTU)

$$CAE = 56.8833 \times \Sigma EP504 \times \Delta\tau$$

SPACE COOLING AUXILIARY THERMAL ENERGY (BTU)

$$CAT = CAE \times 0.70$$

SPACE COOLING OPERATING ENERGY (BTU)

$$COPE = 56.8833 \times \Sigma (EP500 + EP501 + EP502 + EP503 + EP505 + EP506) \times \Delta\tau$$

SPACE COOLING OPERATING ENERGY, SOLAR SPECIFIC (BTU)

$$COPE1 = 56.8833 \times \Sigma (EP500 + EP501 + EP502 + EP505 + EP506)$$

SPACE COOLING LOAD (BTU)

$$CL = TCEL + ATCEL$$

SPACE COOLING SOLAR FRACTION (%)

$$CSFR = TCEL/CL \times 100$$

SPACE COOLING ELECTRIC SAVINGS (BTU)

$$CSVE = TCEL/ATCECOP - COPE1$$

SYSTEM LEVEL PERFORMANCE FACTORS

SYSTEM LOAD (BTU)

$$\text{SYSL} = \text{EHL} + \text{CL}$$

SOLAR ENERGY TO THE LOADS SUBSYSTEM (BTU)

$$\text{SEL} = \text{HSE} + \text{CSE}$$

SYSTEM SOLAR FRACTION OF SYSTEM LOAD (%)

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

TOTAL AUXILIARY ELECTRIC ENERGY TO SYSTEM LOADS (BTU)

$$\text{AXE} = \text{HAE} + \text{CAE}$$

TOTAL AUXILIARY THERMAL ENERGY TO SYSTEM LOADS (BTU)

$$\text{AXT} = \text{CAT} + \text{HAT}$$

POOL OPERATING ENERGY (BTU)

$$\text{POPE} = 56.8833 \times \Sigma (\text{EP401} + \text{EP403}) \times \Delta\tau$$

SYSTEM OPERATING ENERGY (BTU)

$$\text{SYSOPE} = \text{HOPE} + \text{HWOPE} + \text{CSOPE} + \text{POPE}$$

TOTAL ENERGY CONSUMED (BTU)

$$\text{TECSM} = \text{SYSOPE} + \text{SECA} + \text{AXE}$$

TOTAL ELECTRICAL SAVINGS (BTU)

$$\text{TSVE} = \text{HSVE} + \text{CSVE} - \text{CSOPE} - \text{POPE}$$

SOLAR SPECIFIC OPERATING ENERGY (BTU)

$$\text{SYSOPE1} = \text{HOPE1} + \text{HWOPE1} + \text{CSOPE} + \text{POPE}$$

SYSTEM PERFORMANCE FACTOR

$$\text{SYSPF} = \text{SYSL}/(3.33 \times (\text{SYSOPE} + \text{AXE}))$$

SOLAR SAVINGS RATIO

$$\text{SSSR} = \frac{\text{SEL} - (1 - \text{MEFF}) \times \text{YSOPE1}}{\text{SYSL}}$$

ECSS SOLAR CONVERSION EFFICIENCY

$$\text{CSCEF} = \text{SEL}/\text{SEA}$$

APPENDIX E  
LONG-TERM WEATHER DATA



SCOTTSDALE COURTHOUSE LONG-TERM WEATHER DATA

COLLECTOR TILT: 0.00 DEGREES ,  
 LATITUDE: 34.39 DEGREES

LOCATION: SCOTTSDALE, ARIZONA  
 COLLECTOR AZIMUTH: 0.00 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1625.	1021.	0.62833	1.000	1021.	428	0	51.
FEB	2063.	1372.	0.66479	1.000	1372.	292	14	55.
MAR	2605.	1814.	0.69637	1.000	1814.	185	21	60.
APR	3138.	2356.	0.75091	1.000	2356.	60	141	68.
MAY	3487.	2677.	0.76755	1.000	2677.	0	355	76.
JUN	3620.	2739.	0.75669	1.000	2739.	0	588	85.
JUL	3546.	2485.	0.70073	1.000	2485.	0	812	91.
AUG	3265.	2293.	0.70237	1.000	2293.	0	747	89.
SEP	2792.	2017.	0.72236	1.000	2017.	0	564	84.
OCT	2218.	1578.	0.71146	1.000	1578.	17	240	72.
NOV	1726.	1150.	0.66658	1.000	1150.	182	26	60.
DEC	1502.	933.	0.62109	1.000	933.	388	0	53.

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

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

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<sup>1</sup>No. 1 and No. 2 heating oils, diesel fuel, No. 4 fuel oils

<sup>2</sup>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 $\mu$ V/W/m <sup>2</sup>
Temperature Dependence:	± 1% over ambient temperature range -20°C to 40°C
Linearity:	0.5% from 0 to 2,800 W/M <sup>2</sup>
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 <sup>2</sup> -hr
Size:	2" X 2"

**APPENDIX H**  
**TYPICAL MONTHLY DATA**

MONTHLY REPORT: JULY 1981  
 SITE SUMMARY: SCOTTSDALE COURTHOUSE P2234R

CONVENTIONAL UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	178.984 MILLION BTU
	65490 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	19.467 MILLION BTU
	7123 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	93 DEGREES F
AVERAGE BUILDING TEMPERATURE	85 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.10
ECSS OPERATING ENERGY	0.718 MILLION BTU

TOTAL SYSTEM OPERATING ENERGY	4.925 MILLION BTU
TOTAL ENERGY CONSUMED	92.320 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.763	102.410	103.173 MILLION BTU
SOLAR FRACTION	N.A.	0	6	6 PERCENT
SOLAR ENERGY USED	N.A.	0.000	18.707	18.707 MILLION BTU
OPERATING ENERGY	N.A.	0.000	4.207	4.925 MILLION BTU
AUX. THERMAL ENERGY	N.A.	0.763	47.015	47.778 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	0.763	67.164	67.928 MILLION BTU
AUX. FOSSIL FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
ELECTRICAL SAVINGS	N.A.	0.000	3.97	3.25 MILLION BTU
FOSSIL SAVINGS	N.A.	N.A.	N.A.	N.A. MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.43  
 INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 48.92

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.

SOLAR/0004-80/18

READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: JULY 1981  
 SITE SUMMARY: SCOTTSDALE COURTHOUSE P2234R

SI UNITS

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	188.828 GIGA JOULES
	743705 KJ/SQ.M.
COLLECTED SOLAR ENERGY	20.537 GIGA JOULES
	80886 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	34 DEGREES C
AVERAGE BUILDING TEMPERATURE	30 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.10
ECSS OPERATING ENERGY	0.758 GIGA JOULES

TOTAL SYSTEM OPERATING ENERGY	5.196 GIGA JOULES
TOTAL ENERGY CONSUMED	97.397 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	0.805	108.042	108.848 GIGA JOULES
SOLAR FRACTION	N.A.	0	6	6 PERCENT
SOLAR ENERGY USED	N.A.	0.000	19.736	19.736 GIGA JOULES
OPERATING ENERGY	N.A.	0.000	4.439	5.196 GIGA JOULES
AUX. THERMAL ENG	N.A.	0.805	49.601	50.406 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	0.805	70.858	71.664 GIGA JOULES
AUX. FOSSIL FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
ELECTRICAL SAVINGS	N.A.	0.000	4.19	3.43 GIGA JOULES
FOSSIL SAVINGS	N.A.	N.A.	N.A.	N.A. GIGA JOULES

SYSTEM PERFORMANCE FACTOR:	0.43
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS:	48.92

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

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
 ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

JULY 1981

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU (NBS ID) (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	5.763#	93#	0.605#	N	0.023#	0.000#	0.105#
2	5.763#	93#	0.605#	O	0.023#	0.000#	0.105#
3	5.763#	93#	0.605#	T	0.023#	0.000#	0.105#
4	5.763#	93#	0.605#		0.023#	0.000#	0.105#
5	5.763#	93#	0.605#	A	0.023#	0.000#	0.105#
6	5.763#	93#	0.605#	P	0.023#	0.000#	0.105#
7	5.763#	93#	0.605#	P	0.023#	0.000#	0.105#
8	5.668	93	0.107	L	0.035	0.000	0.019
9	6.304	96	0.672	I	0.029	0.000	0.107
10	6.251	95	1.523	C	0.032	0.000	0.244
11	5.470	89	0.588	A	0.035	0.000	0.108
12	6.121	89	0.402	B	0.027	0.000	0.066
13	4.996	90	0.649	L	0.035	0.000	0.130
14	5.452	92	0.587	E	0.035	0.000	0.108
15	6.046	93	0.959		0.032	0.000	0.159
16	6.056	88	1.331		0.031	0.000	0.220
17	6.444	93	1.649		0.027	0.000	0.256
18	5.763#	93#	0.605#		0.023#	0.000#	0.105#
19	6.599	95	1.222		0.016	0.000	0.185
20	6.221	96	0.000		0.000	0.000	0.000
21	6.082	99	0.000		0.000	0.000	0.000
22	3.141	93	0.000		0.000	0.000	0.000
23	5.865	97	0.000		0.010	0.000	0.000
24	6.137	98	0.356		0.032	0.000	0.058
25	5.315	92	0.356		0.020	0.000	0.067
26	5.901	93	0.448		0.023	0.000	0.076
27	5.763#	93#	0.605#		0.023#	0.000#	0.105#
28	5.763#	93#	0.605#		0.023#	0.000#	0.105#
29	5.763#	93#	0.605#		0.023#	0.000#	0.105#
30	5.763#	93#	0.605#		0.023#	0.000#	0.105#
31	5.763#	93#	0.605#		0.023#	0.000#	0.105#
SUM	178.984	-	18.707	N.A.	0.718	0.000	-
AVG	5.774	93	0.603	N.A.	0.023	0.000	0.105
PFRV	0.5108	0.5108	0.5108	N.A.	0.5108	0.5108	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
COLLECTOR SUBSYSTEM PERFORMANCE

JULY 1981

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	5.763#	4.252#	0.611#	102#	0.106#	0.144#
2	5.763#	4.252#	0.611#	102#	0.106#	0.144#
3	5.763#	4.252#	0.611#	102#	0.106#	0.144#
4	5.763#	4.252#	0.611#	102#	0.106#	0.144#
5	5.763#	4.252#	0.611#	102#	0.106#	0.144#
6	5.763#	4.252#	0.611#	102#	0.106#	0.144#
7	5.763#	4.252#	0.611#	102#	0.106#	0.144#
8	5.668	5.409	1.059	111	0.187	0.196
9	6.304	6.114	2.013	106	0.319	0.329
10	6.251	6.148	1.323	104	0.212	0.215
11	5.470	5.315	-0.033	100	-0.006	-0.006
12	6.121	5.953	0.674	100	0.110	0.113
13	4.996	4.905	0.030	99	0.006	0.006
14	5.452	5.340	0.162	102	0.030	0.030
15	6.046	5.894	0.514	103	0.085	0.087
16	6.056	5.912	0.497	97	0.082	0.084
17	6.444	6.334	1.228	103	0.191	0.194
18	5.763#	4.252#	0.611#	102#	0.106#	0.144#
19	6.599	4.371	0.939	102	0.142	0.215
20	6.221	0.000	0.000	105	0.000	0.000
21	6.082	0.000	0.000	108	0.000	0.000
22	3.141	0.000	0.000	96	0.000	0.000
23	5.865	0.806	0.093	106	0.016	0.116
24	6.137	5.947	1.362	107	0.222	0.229
25	5.315	4.210	0.562	98	0.106	0.134
26	5.901	4.926	1.094	103	0.185	0.222
27	5.763#	4.252#	0.611#	102#	0.106#	0.144#
28	5.763#	4.252#	0.611#	102#	0.106#	0.144#
29	5.763#	4.252#	0.611#	102#	0.106#	0.144#
30	5.763#	4.252#	0.611#	102#	0.106#	0.144#
31	5.763#	4.252#	0.611#	102#	0.106#	0.144#
SUM	178.984	132.859	19.467	-	-	-
AVG	5.774	4.286	0.628	103	0.109	0.147
PFRV	0.5108	0.5108	0.5108	0.5108	0.5108	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
SPACE HEATING SUBSYSTEM I

JULY 1981

DAY OF MONTH (NBS ID)	SPACE HEATING	CONTROLLED	TOTAL	TOTAL	SOLAR	ELECT	FOSSIL	BLDG	AMB
	LOAD	DELIVERED	SOLAR	AUXILIARY	FRACTION	ENERGY	ENERGY	TEMP	TEMP
	MILLION	ENERGY	ENERGY	THERMAL	OF LOAD	SAVINGS	SAVINGS	DEG	DEG
	BTU	MILLION	MILLION	USED	PCT	MILLION	MILLION	F	F
	(Q402)	BTU	BTU	BTU	(N400)	BTU	BTU	(N406)	(N113)
			(Q400)	(Q401)		(Q415)	(Q417)		
1	0.025#	0.025#	0.000#	0.025#	0#	0.000#	N	85#	93#
2	0.025#	0.025#	0.000#	0.025#	0#	0.000#	O	85#	93#
3	0.025#	0.025#	0.000#	0.025#	0#	0.000#	T	85#	93#
4	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
5	0.025#	0.025#	0.000#	0.025#	0#	0.000#	A	85#	93#
6	0.025#	0.025#	0.000#	0.025#	0#	0.000#	P	85#	93#
7	0.025#	0.025#	0.000#	0.025#	0#	0.000#	P	85#	93#
8	0.020	0.020	0.000	0.020	0	0.000	L	86	93
9	0.018	0.018	0.000	0.018	0	0.000	I	86	96
10	0.020	0.020	0.000	0.020	0	0.000	C	84	95
11	0.021	0.021	0.000	0.021	0	0.000	A	86	89
12	0.019	0.019	0.000	0.019	0	0.000	B	90	89
13	0.021	0.021	0.000	0.021	0	0.000	L	84	90
14	0.021	0.021	0.000	0.021	0	0.000	E	83	92
15	0.020	0.020	0.000	0.020	0	0.000		84	93
16	0.021	0.021	0.000	0.021	0	0.000		83	88
17	0.021	0.021	0.000	0.021	0	0.000		83	93
18	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
19	0.020	0.020	0.000	0.020	0	0.000		91	95
20	0.019	0.019	0.000	0.019	0	0.000		86	96
21	0.019	0.019	0.000	0.019	0	0.000		85	99
22	0.019	0.019	0.000	0.019	0	0.000		84	93
23	0.024	0.024	0.000	0.024	0	0.000		83	97
24	0.095	0.095	0.000	0.095	0	0.000		84	98
25	0.021	0.021	0.000	0.021	0	0.000		87	92
26	0.022	0.022	0.000	0.022	0	0.000		87	93
27	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
28	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
29	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
30	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
31	0.025#	0.025#	0.000#	0.025#	0#	0.000#		85#	93#
SUM	0.763	0.763	0.000	0.763	-	0.000	N.A.	-	-
AVG	0.025	0.025	0.000	0.025	0	0.000	N.A.	85	93
PFRV	0.5108	0.5108	0.5108	0.5108	0.5108	0.5108	N.A.	0.5108	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
SPACE HEATING SUBSYSTEM II

JULY 1981

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	MEASURED SOLAR ENERGY USED MILLION BTU	SOLAR ENERGY LOSSES TO LOAD MILLION BTU	TOTAL OPERATING ENERGY MILLION BTU (Q403)	SOLAR SPECIFIC OPERATING ENERGY MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q410)	HEATING DEGREE DAYS
1	0.025#	0.000#	N	0.000#	0.000#	0.025#	N	*
2	0.025#	0.000#	O	0.000#	0.000#	0.025#	O	*
3	0.025#	0.000#	T	0.000#	0.000#	0.025#	T	*
4	0.025#	0.000#		0.000#	0.000#	0.025#		*
5	0.025#	0.000#	A	0.000#	0.000#	0.025#	A	*
6	0.025#	0.000#	P	0.000#	0.000#	0.025#	P	*
7	0.025#	0.000#	P	0.000#	0.000#	0.025#	P	*
8	0.020	0.000	L	0.000	0.000	0.020	L	0
9	0.018	0.000	I	0.000	0.000	0.018	I	0
10	0.020	0.000	C	0.000	0.000	0.020	C	0
11	0.021	0.000	A	0.000	0.000	0.021	A	0
12	0.019	0.000	B	0.000	0.000	0.019	B	0
13	0.021	0.000	L	0.000	0.000	0.021	L	0
14	0.021	0.000	E	0.000	0.000	0.021	E	0
15	0.020	0.000		0.000	0.000	0.020		0
16	0.021	0.000		0.000	0.000	0.021		0
17	0.021	0.000		0.000	0.000	0.021		0
18	0.025#	0.000#		0.000#	0.000#	0.025#		*
19	0.020	0.000		0.000	0.000	0.020		0
20	0.019	0.000		0.000	0.000	0.019		0
21	0.019	0.000		0.000	0.000	0.019		0
22	0.019	0.000		0.000	0.000	0.019		0
23	0.024	0.000		0.000	0.000	0.024		0
24	0.095	0.000		0.000	0.000	0.095		0
25	0.021	0.000		0.000	0.000	0.021		0
26	0.022	0.000		0.000	0.000	0.022		0
27	0.025#	0.000#		0.000#	0.000#	0.025#		*
28	0.025#	0.000#		0.000#	0.000#	0.025#		*
29	0.025#	0.000#		0.000#	0.000#	0.025#		*
30	0.025#	0.000#		0.000#	0.000#	0.025#		*
31	0.025#	0.000#		0.000#	0.000#	0.025#		*
SUM	0.763	0.000	N.A.	0.000	0.000	0.763	N.A.	0
AVG	0.025	0.000	N.A.	0.000	0.000	0.025	N.A.	0
PFRV	0.5108	0.5108	N.A.	0.5108	0.5108	0.5108	N.A.	N.A.

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
SPACE COOLING SUBSYSTEM

JULY 1981

DAY OF MONTH (NBS ID)	SPACE COOLING LOAD MILLION BTU (Q502)	SOLAR FRACTION OF LOAD PERCENT (N500)	SOLAR ENERGY USED MILLION BTU (Q500)	OPER ENERGY MILLION BTU (Q503)	AUX THERMAL ENERGY MILLION BTU (Q501)	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q508)	ELECT ENERGY SAVINGS MILLION BTU (Q512)	FOSSIL ENERGY SAVINGS MILLION BTU (Q514)	BLDG DRY BULB TEMP DEG F (N406)	AMB TEMP DEG F (N113)
1	3.326#	6#	0.605#	0.135#	1.527#	2.181#	N		N	85#	93#
2	3.326#	6#	0.605#	0.135#	1.527#	2.181#	O	I	O	85#	93#
3	3.326#	6#	0.605#	0.135#	1.527#	2.181#	T		T	85#	93#
4	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
5	3.326#	6#	0.605#	0.135#	1.527#	2.181#	A		A	85#	93#
6	3.326#	6#	0.605#	0.135#	1.527#	2.181#	P		P	85#	93#
7	3.326#	6#	0.605#	0.135#	1.527#	2.181#	P		P	85#	93#
8	3.689	2	0.107	0.105	1.731	2.473	L		L	86	93
9	3.974	12	0.672	0.188	1.777	2.539	I		I	86	96
10	4.228	20	1.523	0.227	1.750	2.500	C		C	84	95
11	2.931	10	0.588	0.125	1.277	1.824	A		A	86	89
12	0.000	0	0.402	0.000	0.002	0.003	B		B	90	89
H-7 13	4.667	8	0.649	0.169	1.957	2.795	L		L	84	90
14	3.961	7	0.587	0.146	1.793	2.561	E		E	83	92
15	3.921	13	0.959	0.186	1.750	2.500				84	93
16	3.887	10	1.331	0.197	1.696	2.422				83	88
17	3.785	14	1.649	0.237	1.701	2.430				83	93
18	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
19	0.588	0	1.222	0.014	0.249	0.355				91	95
20	4.258	0	0.000	0.111	2.073	2.961				86	96
21	3.668	0	0.000	0.098	1.894	2.706				85	99
22	3.716	0	0.000	0.096	1.745	2.492				84	93
23	3.640	0	0.000	0.096	1.834	2.620				83	97
24	3.842	3	0.356	0.205	1.853	2.647				84	98
25	2.694	4	0.356	0.166	1.261	1.801				87	92
26	1.724	9	0.448	0.085	0.825	1.179				87	93
27	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
28	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
29	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
30	3.326#	6#	0.605#	0.135#	1.527#	2.181#				85#	93#
31	3.326#	6#	0.605#	0.135#	1.527#	2.181#		I		85#	93#
SUM	102.410	-	18.707	4.207	47.015	67.164	N.A.	3.97	N.A.	-	-
AVG	3.304	6	0.603	0.136	1.517	2.167	N.A.	0.13	N.A.	85	93
PFRV	0.5108	0.5108	0.5108	0.5108	0.5108	0.5108	N.A.	0.5108	N.A.	0.51	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
THERMODYNAMIC CONVERSION EQUIPMENT

JULY 1981

DAY OF MONTH	EQUIPMENT LOAD	THERMAL ENERGY INPUT	OPERATING ENERGY	ENERGY REJECTED	COEFFICIENT OF PERFORMANCE (SEE NOTE)
	MILLION BTU	MILLION BTU	MILLION BTU	MILLION BTU	
1	0.232#	0.605#	0.100#	0.798#	0.179#
2	0.232#	0.605#	0.100#	0.798#	0.179#
3	0.232#	0.605#	0.100#	0.798#	0.179#
4	0.232#	0.605#	0.100#	0.798#	0.179#
5	0.232#	0.605#	0.100#	0.798#	0.179#
6	0.232#	0.605#	0.100#	0.798#	0.179#
7	0.232#	0.605#	0.100#	0.798#	0.179#
8	0.063	0.107	0.031	0.192	0.500
9	0.464	0.672	0.128	1.401	0.691
10	0.836	1.523	0.172	2.342	0.549
11	0.288	0.588	0.075	0.849	0.490
12	0.000	0.402	0.256	0.784	0.000
13	0.359	0.649	0.085	0.960	0.553
14	0.289	0.587	0.068	0.779	0.493
15	0.494	0.959	0.127	1.366	0.515
16	0.380	1.331	0.145	1.330	0.286
17	0.521	1.649	0.205	1.706	0.317
18	0.232#	0.605#	0.100#	0.798#	0.179#
19	0.000	1.222	0.122	1.095	0.000
20	0.000	0.000	0.001	0.000	0.000
21	0.000	0.000	0.001	0.000	0.000
22	0.000	0.000	0.003	0.000	0.000
23	0.000	0.000	0.002	0.000	0.000
24	0.123	0.356	0.054	0.355	0.347
25	0.145	0.356	0.168	0.479	0.193
26	0.191	0.448	0.173	0.611	0.244
27	0.232#	0.605#	0.100#	0.798#	0.179#
28	0.232#	0.605#	0.100#	0.798#	0.179#
29	0.232#	0.605#	0.100#	0.798#	0.179#
30	0.232#	0.605#	0.100#	0.798#	0.179#
31	0.232#	0.605#	0.100#	0.798#	0.179#
SUM	7.175	18.707	3.117	24.619	-
AVG	0.231	0.603	0.101	0.794	0.38
PFRV	0.5108	0.5108	0.5108	0.5108	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
 AUXILIARY THERMODYNAMIC CONVERSION EQUIPMENT

JULY 1981

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	ELECTRIC ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	3.093#	2.181#	0.079#	N	1.099#
2	3.093#	2.181#	0.079#	O	1.099#
3	3.093#	2.181#	0.079#	T	1.099#
4	3.093#	2.181#	0.079#		1.099#
5	3.093#	2.181#	0.079#	A	1.099#
6	3.093#	2.181#	0.079#	P	1.099#
7	3.093#	2.181#	0.079#	P	1.099#
8	3.626	2.473	0.087	L	1.278
9	3.510	2.539	0.091	I	1.383
10	3.392	2.500	0.093	C	1.357
11	2.643	1.824	0.068	A	1.450
12	0.000	0.003	0.000	B	0.000
13	4.308	2.795	0.106	L	1.542
14	3.672	2.561	0.094	E	1.434
15	3.427	2.500	0.091		1.371
16	3.507	2.422	0.092		1.448
17	3.264	2.430	0.091		1.308
18	3.093#	2.181#	0.079#		1.099#
19	0.588	0.355	0.014		0.877
20	4.258	2.961	0.106		1.438
21	3.668	2.706	0.094		1.356
22	3.716	2.492	0.092		1.492
23	3.640	2.620	0.092		1.390
24	3.719	2.647	0.094		1.405
25	2.549	1.801	0.064		1.278
26	1.533	1.179	0.042		1.119
27	3.093#	2.181#	0.079#		1.099#
28	3.093#	2.181#	0.079#		1.099#
29	3.093#	2.181#	0.079#		1.099#
30	3.093#	2.181#	0.079#		1.099#
31	3.093#	2.181#	0.079#		1.099#
SUM	95.234	67.164	2.441	*	-
AVG	3.072	2.167	0.079	N.A.	1.42
PFRV	0.5108	0.5108	0.5108	N.A.	0.5108

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

MONTHLY REPORT: SCOTTSDALE COURTHOUSE P2234R  
 ENVIRONMENTAL SUMMARY

JULY 1981

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	2109#	I	93#	102#	N	0#	0#
2	2109#		93#	102#	O	0#	0#
3	2109#		93#	102#	T	0#	0#
4	2109#		93#	102#		0#	0#
5	2109#		93#	102#	A	0#	0#
6	2109#		93#	102#	P	0#	0#
7	2109#		93#	102#	P	0#	0#
8	2074		93	111	L	0	0
9	2307		96	106	I	0	0
10	2287		95	104	C	0	0
11	2001		89	100	A	0	0
12	2240		89	100	B	0	0
13	1828		90	99	L	0	0
14	1995		92	102	E	0	0
15	2212		93	103		0	0
16	2216		88	97		0	0
17	2358		93	103		0	0
18	2109#		93#	102#		0#	0#
19	2415		95	102		0	0
20	2276		96	105		0	0
21	2225		99	108		0	0
22	1149		93	96		0	0
23	2146		97	106		0	0
24	2246		98	107		0	0
25	1945		92	98		0	0
26	2159		93	103		0	0
27	2109#		93#	102#		0#	0#
28	2109#		93#	102#		0#	0#
29	2109#		93#	102#		0#	0#
30	2109#		93#	102#		0#	0#
31	2109#	I	93#	102#		0#	0#
SUM	65490	I	-	-	-	-	-
AVG	2113	I	93	103	N.A.	0	0
PFRV	0.5108	I	0.5108	0.5108	N.A.	0.0000	0.0000

01-H

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