SOLAR/2077-82/14
(DE82020142)

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

SAN ANSELMO SCHOOL

San Jose, California
April 1981 through March 1982
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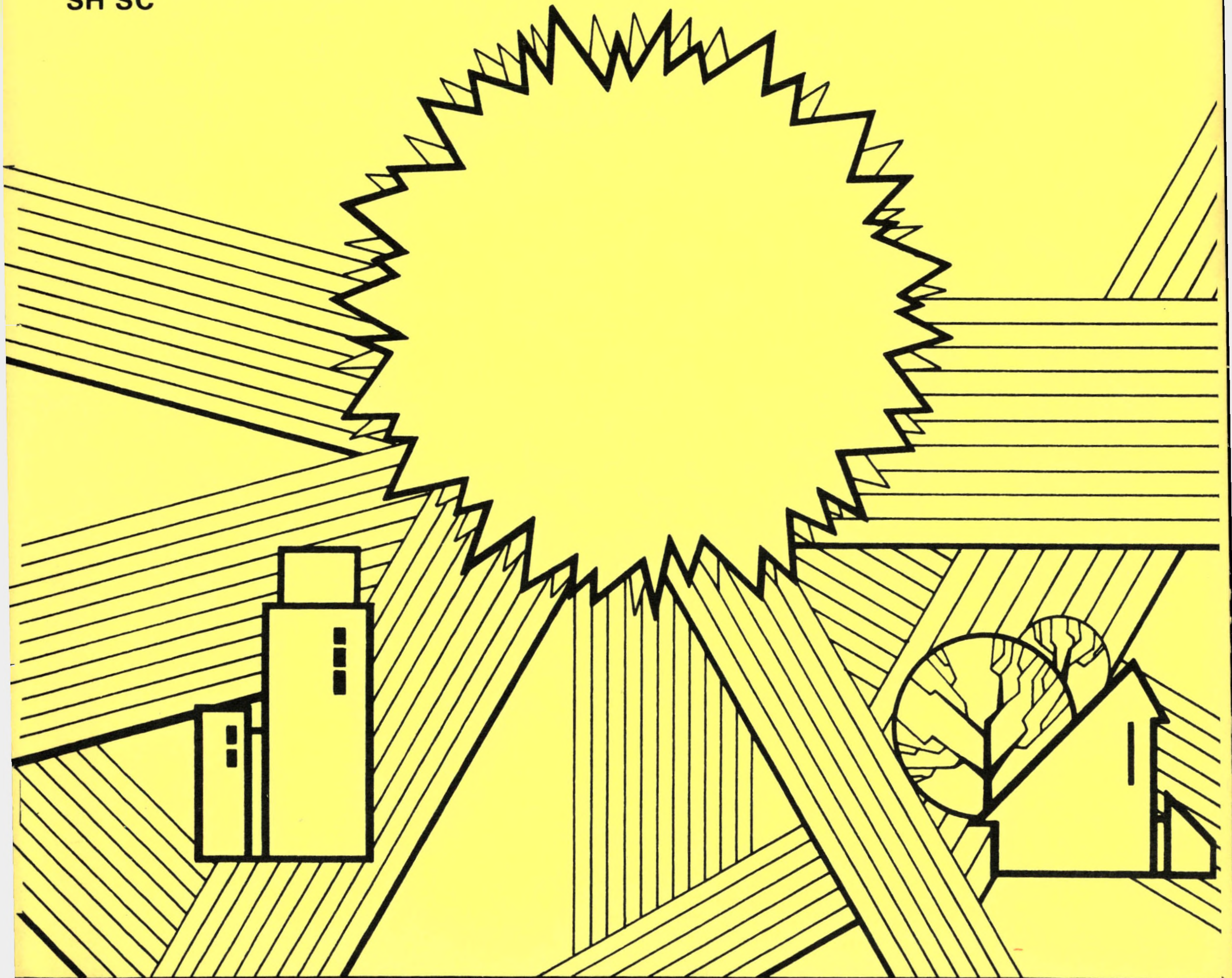

U.S. DEPARTMENT OF ENERGY

NATIONAL SOLAR DATA PROGRAM

SOLAR/2077-82/14
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SAN ANSELMO SCHOOL

SAN JOSE, CALIFORNIA

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

APRIL 1981 THROUGH MARCH 1982

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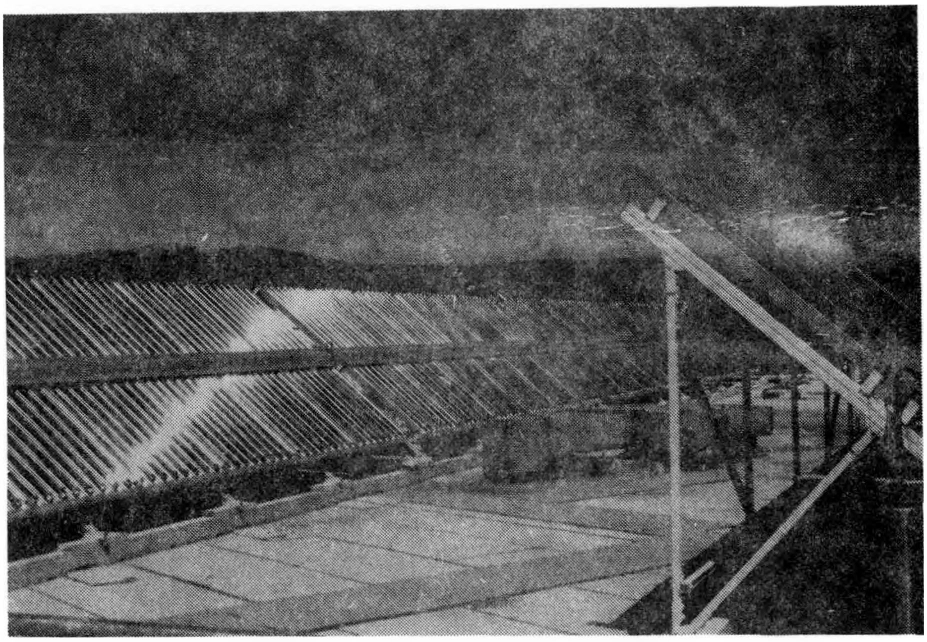
FOREWORD

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

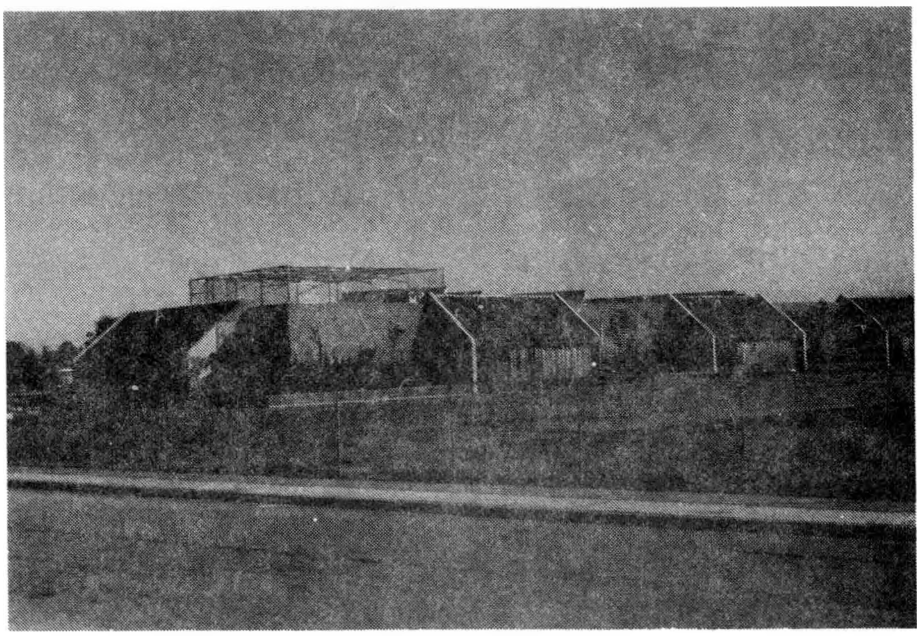
The National Solar Data Network consists of instrumented solar energy systems in buildings selected from among the 5,000 installations built (since early 1977) as part of the National Solar Heating and Cooling Demonstration Program. The overall purpose of this program is to assist in the development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

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

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



Roof-mounted Collector Array



SAN ANSELMO SCHOOL

SAN ANSELMO SCHOOL

The San Anselmo School is a one-story, brick elementary school building located in San Jose, California. The active solar energy system is designed to supply the following:

Annual Design Factors
(Million BTU)

	Total Load	Solar Contribution	% Solar
Heating	232	162	70
Cooling	564	406	72

It is equipped with:

Collector: 3,740 square feet of TC-100 evacuated tube collectors manufactured by General Electric.

Storage: 2,175-gallon tank located outside. Manufactured by Ace Buehler, Inc.

Auxiliary: Four auxiliary gas-fired absorption chiller/heaters (DFE300-600) manufactured by ARKLA Corporation.

Solar Cooling: One solar-supplied absorption chiller (WFB-300) manufactured by ARKLA Corporation.

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SAN ANSELMO SCHOOL
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Solar Fraction[1]	19%
Solar Savings Ratio[2]	0.15
Conventional Fuel Savings[3]	287,560 cubic feet of natural gas at the expense of 6,951 kwh of electrical energy
System Performance Factor[4]	0.18
Solar System COP[5]	7.55

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

	Total Load	Solar Contribution	% Solar
Heating	140.43	32.30	23
Cooling	402.82	74.37	18

Environmental Data

	Measured Average	Long-Term Average
Outdoor temperature	62°F	60°F
Heating degree-days (Total)	2,242	2,416
Cooling degree-days (Total)	914	444
Daily incident solar energy	1,495 BTU/ft^2	1,686 BTU/ft^2

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

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

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

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

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

1.1 SUMMARY AND CONCLUSIONS

The San Anselmo School solar energy system operated below expectations during the April 1981 through March 1982 period. The solar energy system provided 23% of the space heating load and 18% of the space cooling load for a combined contribution of 19% of the system load. The solar energy contribution was below the expected design figures of 70% for the space heating load and 72% of the space cooling load. Severe system control and Heating, Ventilating, and Air Conditioning (HVAC) problems contributed to the poor system performance. Some energy savings and good solar chiller Coefficient of Performance (COP) highlighted the positive aspects of the solar system. The solar system provided a fossil fuel savings of 2,876 therms (287,560 cubic feet) of natural gas at the expense of 6,951 kwh of electrical energy. These energy savings are equivalent to $812.21 based on actual fuel rates at the site. The solar system thermal performance is summarized in Table 1 and shown graphically in Figure 1.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY		OPERATING ENERGY	ENERGY SAVINGS		SOLAR FRACTION (%)
				FOSSIL	THERMAL		FOSSIL	ELECTRICAL	
APR	47.63	34.12	22.68	186.09	103.40	24.15	37.80	-2.87	32
MAY	41.26	41.58	14.16	213.75	120.37	27.19	23.60	-1.91	16
JUN	44.56	69.56	24.43	248.05	143.61	27.44	40.72	-2.53	21
JUL	38.47	67.37	21.75	234.27	135.82	26.58	36.25	-2.08	20
AUG	35.29	56.31	17.10	211.35	121.92	27.74	28.49	-1.85	19
SEP	32.05	61.07	11.81	246.81	142.64	30.05	19.69	-2.18	7
OCT	33.01	45.82	17.93	224.74	126.41	21.23	29.87	-2.34	12
NOV	16.99	26.45	4.73	99.56	50.35	8.27	7.88	-2.19	5
DEC	14.29	26.17	4.53	73.77	31.13	5.26	7.56	-2.00	12
JAN	25.26	54.53	10.60	136.10	73.13	25.25	17.54	-1.91	14
FEB	32.11	28.01	20.01	121.70	64.92	11.91	28.51	-1.04	38
MAR	26.55	32.26	9.42	153.58	85.52	15.39	15.69	-0.84	11
TOTAL	387.47	543.25	179.15	2,149.77	1,199.22	250.46	293.60	-23.74	-
AVERAGE	32.29	45.27	14.93	179.15	99.94	20.87	24.47	-1.98	19(1)

(1)Denotes weighted average.

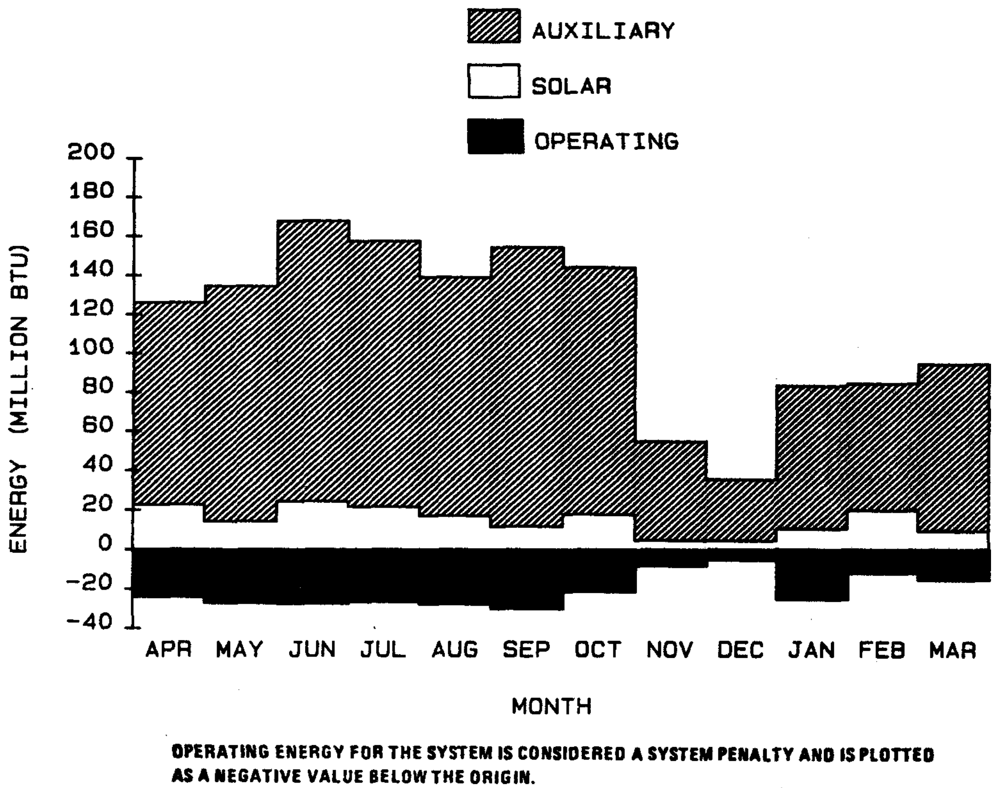

Figure 1. System Thermal Performance
San Anselmo School
April 1981 through March 1982

Several control and HVAC problems were encountered during the reporting period. Those problems having a major impact on system performance are summarized below and are discussed later in more detail.

- Low collector control set point
- Improper set point on the freeze protection control
- Control problem with operation of valve V2
- High storage tank losses
- Solar space heating control problem
- Improper mode control change-over
- Low auxiliary chiller COP
- Improper staging of the absorption chillers
- Mechanical problems with HVAC equipment
- Large gas consumption to keep the chiller units warm
- Building thermostatic control had no provision for an offpoint between heating and cooling.

The flow of solar energy through the San Anselmo School solar system is presented in Figure 2. The Energy Flow Diagram represents the amount of energy collected, transported, lost, and consumed at each point in the system. The diagram shows that 46% of the collected solar energy was used to space condition the school, while 54% of the energy was lost in transfer to the loads. The space heating subsystem shows high losses due to the inefficiency in using an absorption chiller/heater for space heating and the losses in the piping. Note that the air handling unit operating energy is not included in the Energy Flow Diagram. However, it is included in Table 1.

The solar energy Coefficient of Performance (COP) is depicted in Table 2. The COP provides a numerical value for the relationship of solar energy used or collected compared to the amount of electrical energy required to collect or deliver it. The greater the COP value, the more efficient the process. During the reporting period, the overall solar energy system provided a weighted average solar COP value of 7.55. The low solar energy utilization resulted in the low solar COP. The collector subsystem had a COP of 27.58, a good efficiency. Note that during the winter months, collector COP decreased substantially due to freeze protection (see discussion below). The space heating subsystem solar COP was extremely good at 192.44, while the space cooling subsystem solar COP was low at 13.88. The low space cooling solar COP is due to the larger requirements of electrical energy to operate the absorption cooling process.

Table 2. SOLAR COEFFICIENT OF PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	SPACE HEATING SOLAR	SPACE COOLING SOLAR
APR	7.90	35.02	222.67	10.81
MAY	7.41	35.88	412.00	13.39
JUN	9.66	60.22	427.00	12.93
JUL	10.46	69.95	0.00	14.22
AUG	9.24	72.02	0.00	12.57
SEP	5.42	21.80	0.00	16.63
OCT	7.66	24.63	200.00	17.91
NOV	2.16	8.76	0.00	18.92
DEC	2.27	7.37	191.50	17.50
JAN	5.55	13.65	175.33	40.00
FEB	19.24	46.54	213.88	10.74
MAR	11.21	50.09	91.00	18.73
WEIGHTED AVERAGE	7.55	27.58	192.44	13.88

The collector subsystem performance for the San Anselmo School is shown in Table 3. The total incident solar radiation upon the collector array was

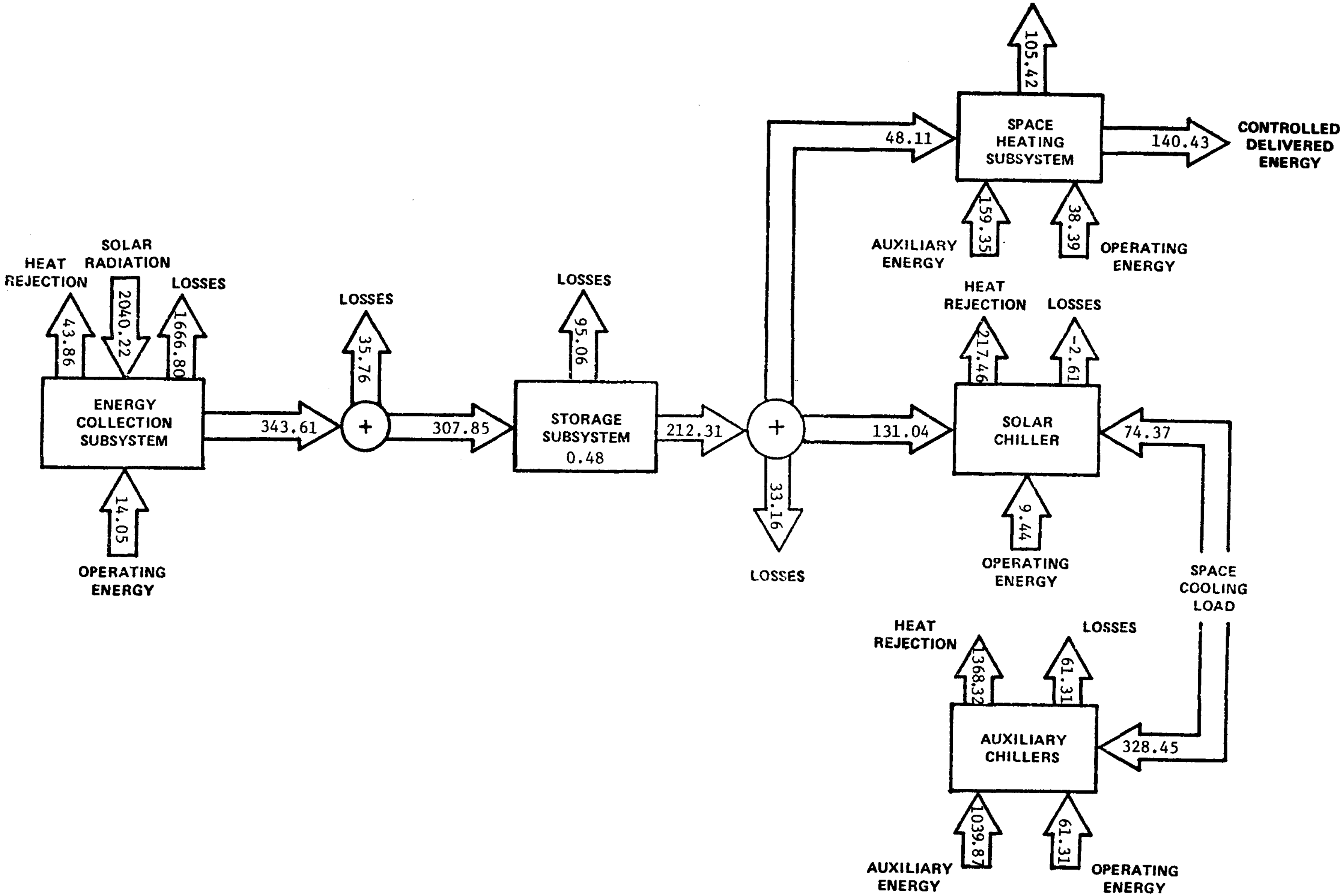

Figure 2. Energy Flow Diagram for San Anselmo School
April 1981 through March 1982
(Figures in million BTU)

Table 3. COLLECTOR SUBSYSTEM PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	COLLECTED SOLAR ENERGY	COLLECTOR SUBSYSTEM EFFICIENCY (%)	OPERATIONAL INCIDENT ENERGY	COLLECTOR ARRAY OPERATIONAL EFFICIENCY (%)	ECSS REJECTED ENERGY	ECSS OPERATING ENERGY	SOLAR ENERGY TO LOADS	SOLAR ENERGY TO STORAGE	DAYTIME AMBIENT TEMPERATURE (°F)
APR	209.64	47.63	23	208.61	23	6.22	1.36	22.68	35.70	71
MAY	198.47	41.26	21	197.01	21	7.24	1.15	14.16	25.97	74
JUN	204.88	44.56	22	177.54	25	5.17	0.74	24.43	35.64	84
JUL	209.93	38.47	18	158.45	24	3.57	0.55	21.75	31.68	85
AUG	212.22	35.29	17	151.84	23	2.76	0.49	17.10	29.91	83
SEP	197.25	32.05	16	155.25	21	7.54	1.47	11.81	19.81	79
OCT	174.72	33.01	19	141.83	23	3.17	1.34	17.93	29.54	71
NOV	116.56 E	16.99	15 E	115.21 E	15 E	2.07	1.94	4.73	13.27	64
DEC	93.02 E	14.29	15 E	92.67 E	15 E	0.06	1.94	4.53	13.24	58
JAN	135.95	25.26	19	135.35	19	0.64	1.85	10.60	22.54	53
FEB	143.26	32.11	22	125.77	26	0.62	0.69	20.01	30.97	62
MAR	144.32	26.55	18	123.37	22	4.80	0.53	9.42	19.58	60
TOTAL	2,040.22	387.47	-	1,782.90	-	43.86	14.05	179.15	307.85	-
AVERAGE	170.02	32.29	19(1)	148.58	22(1)	3.66	1.17	14.93	25.65	70

E Denotes estimated value.
(1)Denotes weighted average.

2,040.22 million BTU, while there were 1,782.90 million BTU of solar radiation incident during collector pump operation. The collector array absorbed 387.47 million BTU of energy, representing a collector array efficiency of 19% and a collector array operational efficiency of 22%. The collector subsystem consumed 14.05 million BTU of electrical energy to operate the collector pump and heat rejection fan. Since the collector array is composed of evacuated-tube collectors that can obtain high temperatures, it was necessary to reject 43.86 million BTU of collected energy to protect the subsystem from overheating.

The collector performance was lower than expected during the reporting period due to the low collector control set point, improper set point for freeze protection, and operating at higher collector inlet temperatues due to the valve V2 control mechanism. The low collector control set point starts the collector pump too early and continues operation beyond positive collection levels. This results in low or negative collected energy. The improper set point for the freeze protection mode activates the collector pump whenever the ambient temperature falls below 49°F. This usually occurs at nighttime and, at times, removes energy from storage. The improper set point added to the operating costs. (The collector control and freeze protection set point were corrected in February 1982.)

The control mechanism for valve V2 allows collected energy to storage when the collector outlet exceeds 165°F.

A collector outlet temperature below 165°F will result in the recirculation of flow within the collector loop and will result in high collector inlet temperatures. This causes lower collector efficiencies during the collector recirculation periods. These problems all contributed to the lower collector performance.

A plot of the collector array efficiency for October 1981 is depicted in Figure 3. The manufacturer's curve is also illustrated to compare the efficiency levels. The actual array efficiency is lower than the single-panel efficiency, primarily due to the problems mentioned above. Some broken evacuated tubes and collector degradation also contributed to the drop in collector efficiency. Observations from other NSDN systems indicate similar deviations from single-panel efficiencies versus actual collector array efficiencies. (The curve shown in Figure 3 is typical of the array efficiency at this site for any month during the season.)

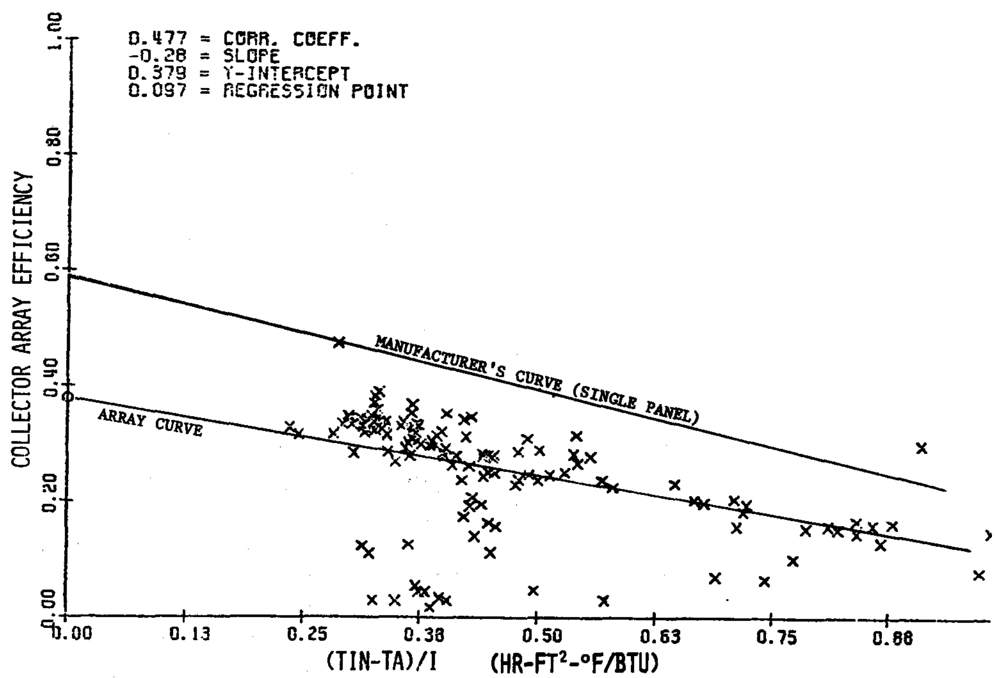

Figure 3. Average Collector Efficiency
San Anselmo School
October 1981

Of the 387.47 million BTU of collected solar energy, 307.85 million BTU were delivered to the storage subsystem, see Table 4. Because of the valve V2 control device, solar energy transfer to storage was delayed. This resulted in less energy to storage, higher line losses, and delayed solar chiller operation. Due to control problems which prevented the full usage of stored energy, a total of 212.31 million BTU was removed from the storage tank. The change in stored energy was 0.48 million BTU. The total storage loss was 95.06 million BTU and the storage efficiency was 69%. The large storage loss is primarily due to space heating control problems which caused an under utilization of the energy available. Since the storage tank is located outside, the energy was lost from storage and did not reduce heating loads or add to cooling loads.

Table 4. STORAGE PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMPERATURE (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (Btu/hr-ft²-°F)	LOSS FROM STORAGE
APR	35.70	25.92	0.48	74	166	0.52	9.30
MAY	25.97	19.77	0.62	79	171	0.35	5.58
JUN	35.64	29.67	-0.64	81	169	0.38	6.61
JUL	31.68	25.52	0.01	81	168	0.32	6.15
AUG	29.91	20.89	0.66	72	168	0.47	8.36
SEP	19.81	15.42	-0.67	74	161	0.30	5.06
OCT	29.54	21.53	0.46	74	163	0.41	7.55
NOV	13.27	6.11	-0.67	41	165	0.39	7.83
DEC	13.24	4.85	-0.75	31	138	0.55	9.14
JAN	22.54	10.80	1.24	53	132	0.69	10.50
FEB	30.97	21.62	-0.06	70	147	0.60	9.41
MAR	19.58	10.21	-0.20	51	160	0.57	9.57
TOTAL	307.85	212.31	0.48	-	-	-	95.06
AVERAGE	25.65	17.69	0.04	69(1)	159	0.46	7.92

(1)Denotes weighted average.

The space heating subsystem performance, Tables 5 and 5a, was very poor during the reporting period. The heating subsystem used 48.11 million BTU of solar energy and 159.35 million BTU of auxiliary energy to supply a space heating load of 140.43 million BTU. Solar energy supplied 23% of the energy requirements. The large losses were due to absorption chiller/heater inefficiencies, line losses, and the two-pipe system for heating and cooling. Actual loads were 68% of the input energy.

The solar contribution was only 23% as compared to the design figure of 70%. A control problem prevented the use of solar energy to the space heating load although solar energy was available in the storage tank. This problem severely reduced the solar contribution and, at times, resulted in no solar contribution. A large natural gas consumption occurred during the reporting period. A total of 1,480 therms (148,000 cubic feet) of natural gas was consumed to keep the chiller units warm. (This energy is not included in the space heating or cooling fossil energy, but is in the total value.) None of this energy was used to condition the school. According to the ARKLA manual, the units require energy to maintain a certain set point temperature. There was a small space heating load during May and June 1981, which was due to an improper control mode activation which caused the system to operate in the space heating mode when space cooling was required. [The mode control problem was repaired in June 1981 and the space heating controls were repaired on

Table 5. SPACE HEATING SUBSYSTEM

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	CONTROLLED DELIVERED ENERGY	TOTAL SOLAR ENERGY USED	TOTAL AUXILIARY THERMAL USED	SOLAR FRACTION OF LOAD (%)	BLDG TEMP (°F)	AMB TEMP (°F)
APR	1.64	1.64	6.68	1.37	83	73	60
MAY	0.43	0.43	4.12	0.00	100	76	64
JUN	0.75	0.75	1.28	0.03	98	79	73
JUL	0.00	0.00	0.00	0.00	0	77	72
AUG	0.00	0.00	0.00	0.00	0	76	72
SEP	0.57	0.57	0.00	1.66	0	76	70
OCT	3.95	3.95	0.02	9.35	0	73	62
NOV	13.05	13.05	0.00	19.03	0	71	58
DEC	25.14	25.14	3.83	26.84	12	69	52
JAN	52.47	52.47	10.52	59.17	15	67	46
FEB	20.62	20.62	17.11	16.29	51	70	55
MAR	21.81	21.81	4.55	25.61	15	71	54
TOTAL	140.43	140.43	48.11	159.35	-	-	-
AVERAGE	11.70	11.70	4.01	13.28	23(1)	73	62

(1) Denotes Weighted Average

Table 5a. SPACE HEATING SUBSYSTEM (Continued)

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	MEASURED SOLAR ENERGY USED	TOTAL OPERATING ENERGY	SOLAR-SPECIFIC OPERATING ENERGY	FOSSIL ENERGY SAVINGS	AUXILIARY FOSSIL FUEL	HEATING DEGREE-DAYS
APR	1.64	6.68	1.99	0.03	11.13	2.29	197
MAY	0.43	4.12	0.01	0.01	6.86	0.00	81
JUN	0.75	1.28	0.02	0.00	2.13	0.05	5
JUL	0.00	0.00	0.00	0.00	0.00	0.00	0
AUG	0.00	0.00	0.00	0.00	0.00	0.00	0
SEP	0.57	0.00	0.83	0.00	0.00	2.77	4
OCT	3.95	0.02	0.95	0.00	0.03	15.59	112
NOV	13.05	0.00	1.19	0.00	0.00	31.71	215
DEC	25.14	3.83	2.28	0.02	6.39	44.73	389
JAN	52.47	10.52	21.33	0.06	17.54	98.62	596
FEB	20.62	17.11	3.80	0.08	28.51	27.15	289
MAR	21.81	4.55	5.99	0.05	7.58	42.68	354
TOTAL	140.43	48.11	38.39	0.25	80.17	265.59	2,242
AVERAGE	11.70	4.01	3.20	0.02	6.68	22.13	187

April 7, 1982 during a troubleshooting effort by the Energy Technology Engineering Center (ETEC)]. If the controls and problems mentioned above were corrected, the solar space heating performance could possibly meet the design performance.

Space cooling for the San Anselmo Elementary School is provided by four auxiliary gas-fired absorption chillers and a solar-supplied absorption chiller. Space cooling is initiated and terminated by a time clock control which typically operates Monday through Friday from 7:00 a.m. to 3:30 p.m. During system operation, the interior thermostats determine the space cooling needs of the building. The space cooling performance during the reporting period is presented in Table 6 and the solar and auxiliary absorption chiller performances are shown in Tables 7 and 8.

The space cooling load of 402.82 million BTU was satisfied by 131.04 million BTU of solar energy and 1,039.87 million BTU of auxiliary thermal energy. The solar fraction of the load was 18% with an operating energy expense of 198.02 million BTU.

Table 6. SPACE COOLING SUBSYSTEM

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	COOLING LOAD	SOLAR FRACTION OF LOAD (%)	SOLAR ENERGY USED	OPERATING ENERGY	AUX THERMAL USED	AUX FOSSIL FUEL	FOSSIL ENERGY SAVINGS	BUILDING TEMPERATURE (°F)
APR	32.48	29	16.00	20.80	102.03	170.05	26.67	73
MAY	41.15	15	10.04	26.03	120.37	200.61	16.74	76
JUN	68.81	20	23.15	26.68	143.58	239.31	38.59	79
JUL	67.37	20	21.75	26.03	135.82	226.37	36.25	77
AUG	56.31	19	17.10	27.25	121.92	203.20	28.49	76
SEP	60.50	12	11.81	27.75	140.98	234.96	19.69	76
OCT	41.87	25	17.91	18.94	117.06	195.09	29.84	73
NOV	13.40	17	4.73	5.14	31.32	52.21	7.88	71
DEC	1.03	31	0.70	1.04	4.29	7.15	1.17	69
JAN	2.06	0	0.08	2.07	13.96	23.27	0	67
FEB	7.39	0	2.90	7.42	48.63	81.06	0	70
MAR	10.45	4	4.87	8.87	59.91	99.86	8.11	71
TOTAL	402.82	-	131.04	198.02	1,039.87	1,733.14	213.43	-
AVERAGE	33.57	18(1)	10.92	16.50	86.66	144.43	17.79	73

(1)Denotes weighted average.

Table 7. SOLAR CHILLER PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	EQUIPMENT LOAD	THERMAL ENERGY INPUT	OPERATING ENERGY	REJECTED ENERGY	COEFFICIENT OF PERFORMANCE (RATIO)
APR	9.65	16.00	1.48	25.22	0.60
MAY	5.98	10.04	0.75	16.85	0.60
JUN	14.49	23.15	1.79	40.67	0.63
JUL	13.23	21.75	1.53	37.19	0.61
AUG	10.48	17.10	1.36	29.66	0.61
SEP	7.14 E	11.81	0.71	20.43	0.60
OCT	10.46 E	17.91	1.00	30.97	0.58
NOV	2.23 E	4.73	0.25	7.30	0.47
DEC	0.32 E	0.70	0.04	0.89	0.46
JAN	0.00	0.08	0.00	0.00	0.00
FEB	-0.03	2.90	0.27	2.67	0.00
MAR	0.42	4.87	0.26	5.61	0.09
TOTAL	74.37	131.04	9.44	217.46	-
AVERAGE	6.20	10.92	0.79	18.12	0.57[1]

E Denotes estimated value.
(1) Denotes weighted average.

Table 8. AUXILIARY CHILLER PERFORMANCE

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	EQUIPMENT LOAD	THERMAL ENERGY INPUT	OPERATING ENERGY	REJECTED ENERGY	COEFFICIENT OF PERFORMANCE (RATIO)
APR	22.83	102.03	6.45	124.97	0.22
MAY	35.17	120.37	8.27	155.64	0.29
JUN	54.32	143.58	7.69	197.79	0.38
JUL	54.14	135.82	7.26	189.96	0.40
AUG	45.83	121.92	8.08	167.77	0.38
SEP	53.36	140.98	9.07	197.20	0.38
OCT	31.41	117.06	5.94	145.41	0.27
NOV	11.17	31.32	1.56	43.42	0.36
DEC	0.71	4.29	0.38	5.19	0.17
JAN	2.06	13.96	0.81	16.02	0.15
FEB	7.42	48.63	2.64	55.32	0.15
MAR	10.03	59.91	3.16	69.63	0.17
TOTAL	328.45	1,039.87	61.31	1,368.32	
AVERAGE	27.37	86.66	5.11	114.03	0.32[1]

(1) Denotes weighted average.

The solar chiller performed very well at an average COP of 0.57 while the auxiliary chiller performance was poor at an average COP of 0.32. The solar chiller operated well, but the overall solar contribution of 18% was low compared to the design solar cooling fraction of 72%.

Since the solar chiller is not activated until storage temperatures approach 185°F, the control malfunction on valve V2 delayed chiller operation. (Refer to collector and storage discussion.) Another control problem allowed cold water to return to the storage tank. The cold water returning to the storage tank was a result of the system improperly switching to the heating mode when space cooling was required. This cold water also delayed or prevented chiller startup. (The problem was repaired in June 1981.)

Auxiliary absorption chiller problems in the cooling mode lowered the chiller COP and caused a higher consumption of fossil fuel. The auxiliary chillers lost the vacuum in the low pressure chamber which resulted in low COPs because the chillers could not produce the required output per given input of natural gas. Also, improper staging of the auxiliary chillers required a proportionally greater energy input for a small increase in chilled water production. The improper staging activates all the auxiliary chillers even though the required demand is very low. This resulted in large quantities of auxiliary energy usage and low chiller COP. The staging control is supposed to allow a small time delay during startup conditions between chillers, and then stage the chillers according to return temperature from the loads. The staging control did not work properly.

Overall, the space cooling subsystem performance was poor. The solar absorption chiller converted solar energy very efficiently to produce chilled water, whereas the auxiliary absorption chillers produced chilled water approximately one half as efficiently. However, the solar contribution of 18% could have been improved providing the system controls and HVAC equipment were working efficiently. A refurbishment effort of the solar system was conducted during April 1982. Most of the problems have not been corrected and system performance is not expected to change substantially.

Measured monthly values of the solar-unique operating energies for the San Anselmo School solar energy system are presented in Table 9. Table 9 depicts the solar-unique operating energies for each subsystem as well as the total solar specific operating energy during the reporting period.

Operating energy is defined as the electrical energy required to support the functioning of the collector, storage, space heating, and space cooling subsystems without directly affecting their thermal states. This energy is interpreted as pumping energy, fan power, and electrical energy required to operate all the components of the solar energy system.

The solar unique operating energy for the San Anselmo School is divided into three subsystems. The energy collection and storage subsystem (ECSS) requires operating energy for pump P8 and heat rejector fan power. The space heating subsystem (SHS) requires operating energy for pump P7. The space cooling subsystem (SCS) requires operating energy for pump P7, pump P1, solar chiller power, and a weighted contribution of the cooling tower fans and pump P6. All of the above items are considered solar-unique operating energy.

Table 9. SOLAR-UNIQUE OPERATING ENERGY

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	SHS OPERATING ENERGY	SCS OPERATING ENERGY	SOLAR-UNIQUE OPERATING ENERGY
APR	1.36	0.03	1.48	2.87
MAY	1.15	0.01	0.75	1.91
JUN	0.74	0.00	1.79	2.53
JUL	0.55	0.00	1.53	2.08
AUG	0.49	0.00	1.36	1.85
SEP	1.47	0.00	0.71	2.18
OCT	1.34	0.00	1.00	2.34
NOV	1.94	0.00	0.25	2.19
DEC	1.94	0.02	0.04	2.00
JAN	1.85	0.06	0.00	1.91
FEB	0.69	0.08	0.27	1.04
MAR	0.53	0.05	0.26	0.84
TOTAL	14.05	0.25	9.44	23.74
AVERAGE	1.17	0.02	0.79	1.98

Total solar-unique operating energy of 23.74 million BTU was utilized while the auxiliary heating and cooling system consumed 226.72 million BTU of operating energy. The solar-unique operating energy represents nine percent of the total system energy. The major portion of the system operating energy occurs within the space cooling subsystem.

Energy savings for the San Anselmo School from April 1981 through March 1982 are presented in Table 10. During the twelve-month period, the total savings were 293.60 million BTU of fossil fuel (natural gas) with an electrical energy expense of 23.74 million BTU. These savings are equivalent to 287,560 cubic feet (2,876 therms) of natural gas at the expense of 6,951 kwh of electrical energy.

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

Table 10. ENERGY SAVINGS

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING ELECTRICAL	SPACE HEATING FOSSIL FUEL	SPACE COOLING ELECTRICAL	SPACE COOLING FOSSIL FUEL	ECSS OPERATING ENERGY SOLAR-UNIQUE	NET ENERGY SAVINGS ELECTRICAL	NET ENERGY SAVINGS FOSSIL FUEL
APR	22.68	-0.03	11.13	-1.48	26.67	-1.36	-2.87	37.80
MAY	14.16	-0.01	6.86	-0.75	16.74	-1.15	-1.91	23.60
JUN	24.43	0.00	2.13	-1.79	38.59	-0.74	-2.53	40.72
JUL	21.75	0.00	0.00	-1.53	36.25	-0.55	-2.08	36.25
AUG	17.10	0.00	0.00	-1.36	28.49	-0.49	-1.85	28.49
SEP	11.81	0.00	0.00	-0.71	19.69	-1.47	-2.18	19.69
OCT	17.93	0.00	0.03	-1.00	29.84	-1.34	-2.34	29.87
NOV	4.73	0.00	0.00	-0.25	7.88	-1.94	-2.19	7.88
DEC	4.53	-0.02	6.39	-0.04	1.17	-1.94	-2.00	7.56
JAN	10.60	-0.06	17.54	0.00	0.00	-1.85	-1.91	17.54
FEB	20.01	-0.08	28.51	-0.27	0.00	-0.69	-1.04	28.51
MAR	9.42	-0.05	7.58	-0.26	8.11	-0.53	-0.84	15.69
TOTAL	179.15	-0.25	80.17	-9.44	213.43	-14.05	-23.74	293.60
AVERAGE	14.93	-0.02	6.68	-0.79	17.79	-1.17	-1.98	24.47

The overall savings in dollars are approximately $812.21 for the twelve-month period. The computed savings are based on an actual fuel rate at the site of $0.50 per therm (100 ft^3) of natural gas and $0.09 per kwh of electrical energy.

The auxiliary energy sources for the space heating and cooling subsystems are four natural-gas-fired absorption chiller/heaters. The natural-gas-fired units are considered to be 60% efficient for computing energy savings.

The weather conditions during the reporting period are displayed in Table 11. The measured insolation was lower than the long-term predictions, primarily due to the poor sunshine during the winter season of 1981-1982. However, the measured average ambient temperature was two degrees higher than the long-term average. The typical insolation throughout the reporting period has shown morning cloud cover or haze due to the local terrain and microclimate. The heating degree-days agree very well, but the measured cooling degree-days were approximately twice the long-term predictions.

Table 11. WEATHER CONDITIONS

SAN ANSELMO SCHOOL
APRIL 1981 THROUGH MARCH 1982

MONTH	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT^2-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
APR	1,868	1,944	60	58	197	228	34	12
MAY	1,712	1,952	64	62	81	123	41	20
JUN	1,826	1,947	73	66	5	50	236	71
JUL	1,811	1,978	72	68	0	12	230	117
AUG	1,830	1,958	72	68	0	15	212	111
SEP	1,758	1,929	70	68	4	13	146	94
OCT	1,507	1,671	62	63	112	90	14	19
NOV	1,039 E	1,332	58	56	215	276	1	0
DEC	802 E	1,123	52	50	389	456	0	0
JAN	1,173	1,172	46	50	596	481	0	0
FEB	1,368	1,463	55	53	289	350	0	0
MAR	1,245	1,768	54	55	354	322	0	0
TOTAL	-	-	-	-	2,242	2,416	914	444
AVERAGE	1,495	1,686	62	60	187	201	76	37

E Denotes estimated value.

1.2 SYSTEM OPERATION

1.2.1 TYPICAL SYSTEM OPERATION

April 7, 1981 represents an excellent sunny day of system operation for the San Anselmo School solar site. The variation of key solar system parameters for this day is presented in Figures 4a, 4b, and 4c.

Figure 4a depicts the solar radiation incident upon the collector array at a 40 degree tilt from the horizontal. This figure shows a very clear day of sunshine with a slight drop of insolation before noon. The maximum intensity was 322 BTU/ft^2-hr. The collector operating period is also shown. Due to the control set point, the collector pump was operated during the major portion of the available insolation.

The collector array inlet and outlet temperatures are depicted in Figure 4b. The collector pump was activated at 0708 hours when the collector control reached its set point. Between 0708 and 0942 hours, the collector array inlet and outlet temperature difference was very small, but the collector temperatures rose very quickly. The collector fluid temperatures rose because the fluid was recirculating within the collector loop. At 0942 hours, solar energy was added to the storage tank. The collector array inlet and outlet temperature differential was large, which shows good collector performance as

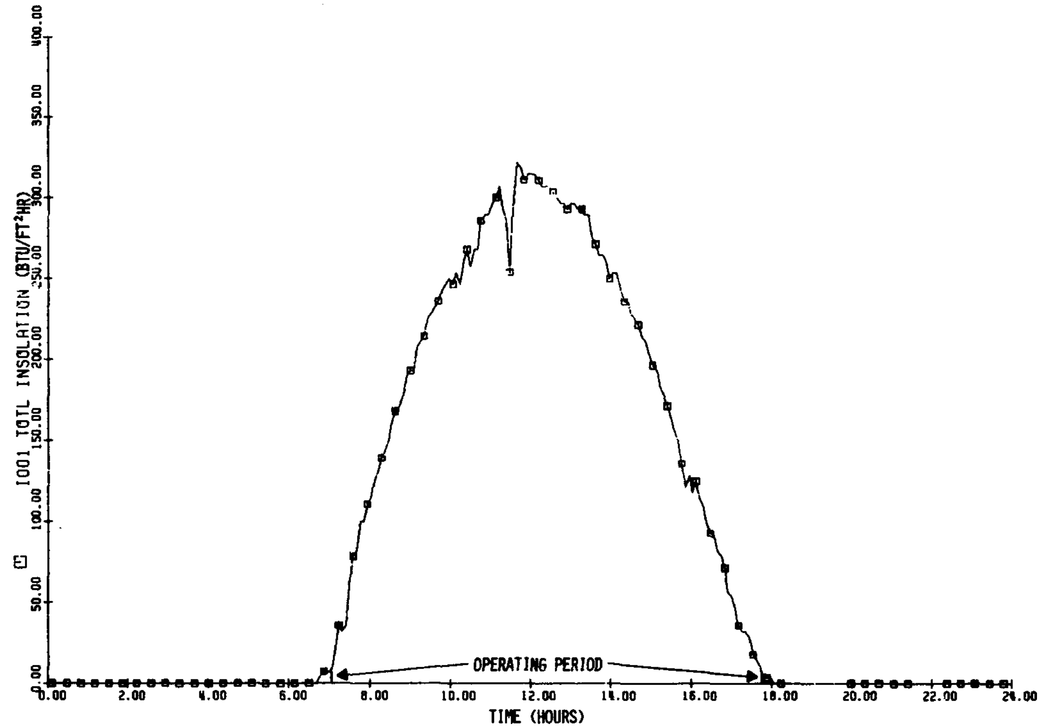

Figure 4a. Typical Insolation Data
San Anselmo School
April 7, 1981

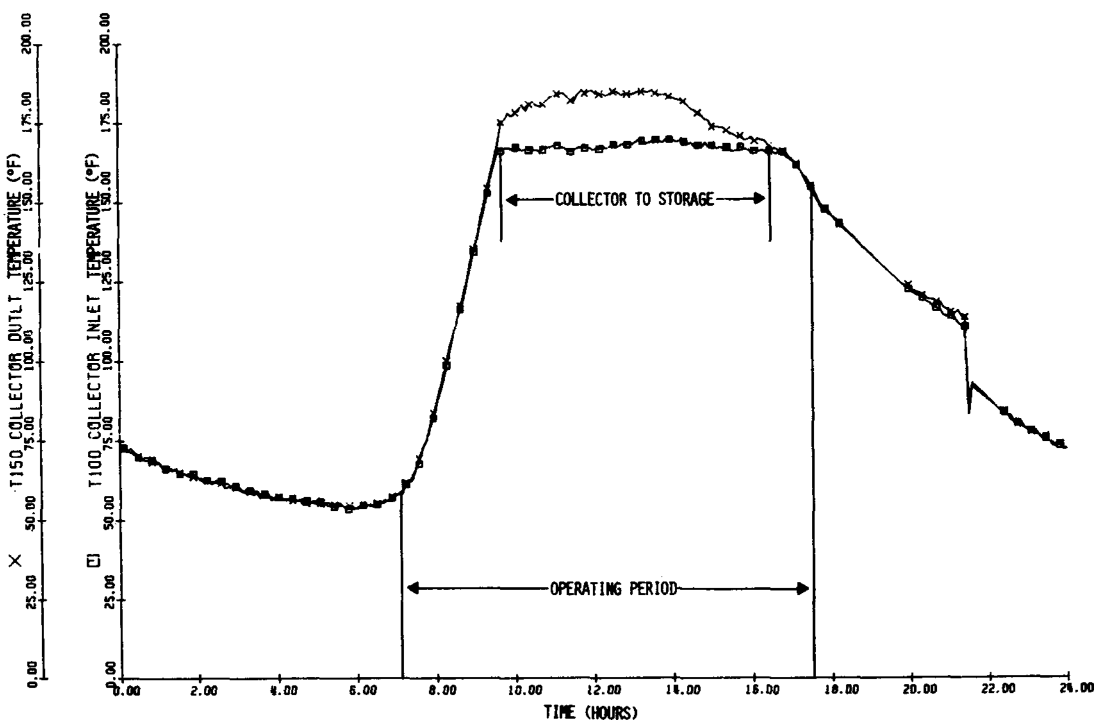

Figure 4b. Typical Collector Array Temperatures, Inlet/Outlet
San Anselmo School
April 7, 1981

a result of using lower collector inlet temperatures from storage. The temperature difference profile shows good solar energy collection until the insolation levels began to decline. At 1628 hours, the storage tank was bypassed and the collector inlet and outlet temperature difference was once again very small. At 1742 hours, the collector pump was turned off by the controller. The control device for valve V2 allowed flow to the storage tank whenever the collector outlet temperature exceeded 165°F.

The storage tank temperature profile is presented in Figure 4c. The tank temperatures gradually declined in the morning hours except for the period between 0454 and 0718 hours when solar energy was used for space heating. At these times, the storage tank exhibited high stratification which is desirable to utilize the highest temperature from the top of the storage tank. At 0942 hours, energy was added to the storage tank and the temperature rose to a maximum of 183°F. Beginning at 1201 hours, the solar chiller began to consume energy from storage. But the solar cooling controller caused a cycling effect which can be seen by the mid-tank temperature sensor fluctuations. The tank temperatures began to fall as energy was removed from the storage tank until 1540 hours, when the solar chiller was turned off. The storage tank temperatures again rose because of solar energy being added to storage. At 1628 hours, no energy was added or removed from storage and the storage tank temperatures declined due to storage losses to the ambient. The storage tank showed high tank stratification and, therefore, provided usage of the hottest water available.

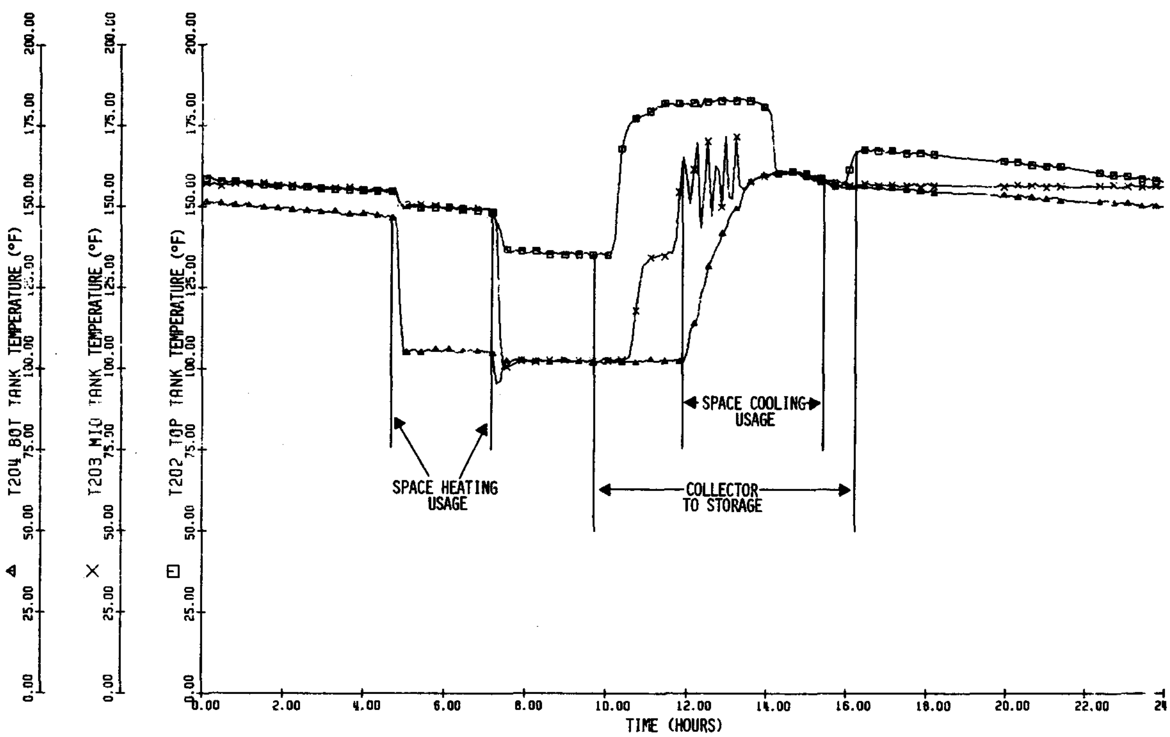

Figure 4c. Typical Storage Fluid Temperatures
San Anselmo School
April 7, 1981

1.2.2 SYSTEM OPERATING SEQUENCE

Figure 5 represents a bar chart depicting a typical system operating sequence for April 7, 1981. This data correlates with the curves presented in Figures 4a, 4b, and 4c, and provides additional information on system operation.

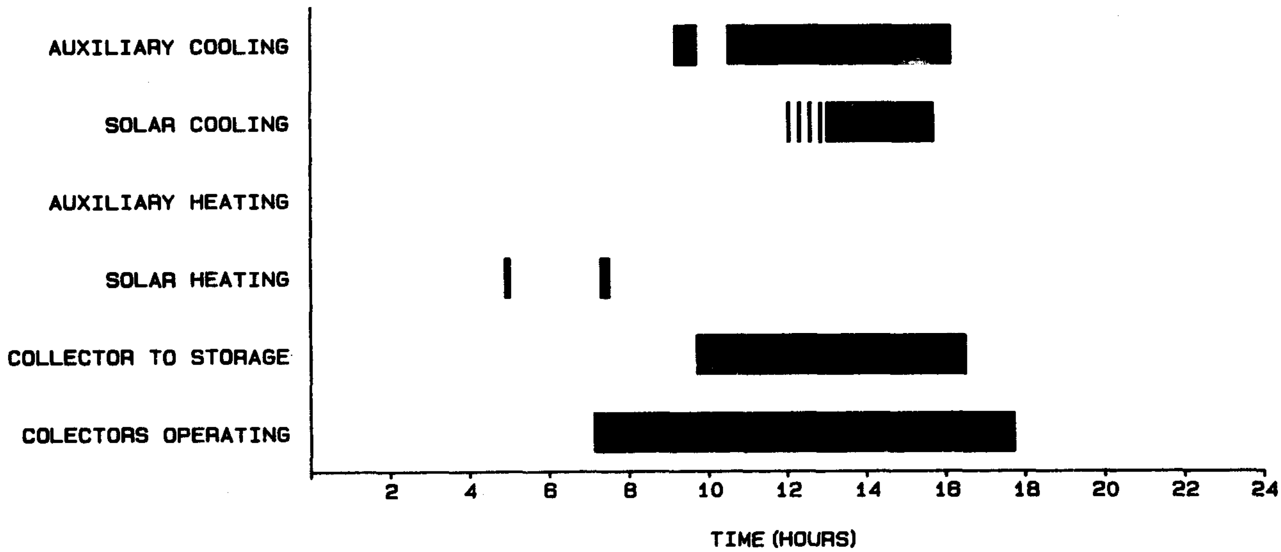

Figure 5. Typical System Operating Sequence
San Anselmo School
April 7, 1981

The San Anselmo School space conditioning equipment is initially activated by a time clock control. The building thermostat then controls the space conditioning needs of the school. From Figure 5, it can be seen that the school required some small amounts of space heating in the early morning and space cooling from about 0900 hours until 1600 hours. Only solar energy was required for space heating, but a combination of solar and auxiliary energy was needed to cool the building. The collector pump operated during most of the day, but only a portion of the collected energy was added to the storage tank.

1.3 SOLAR ENERGY UTILIZATION

Figure 6 shows the use of solar energy and the percentage of losses for the San Anselmo School solar energy system.

The system demonstrates very small threshold losses due to the control device activating the collector pump during most of the available insolation. The large collector inefficiency was caused by operating at higher collector inlet temperatures and the low set point of the collector controller.

The collector to storage losses were low, but the storage tank losses were high. The energy delivered to the load subsystems was nine percent of the available solar radiation. Severe control problems caused the low solar utilization.

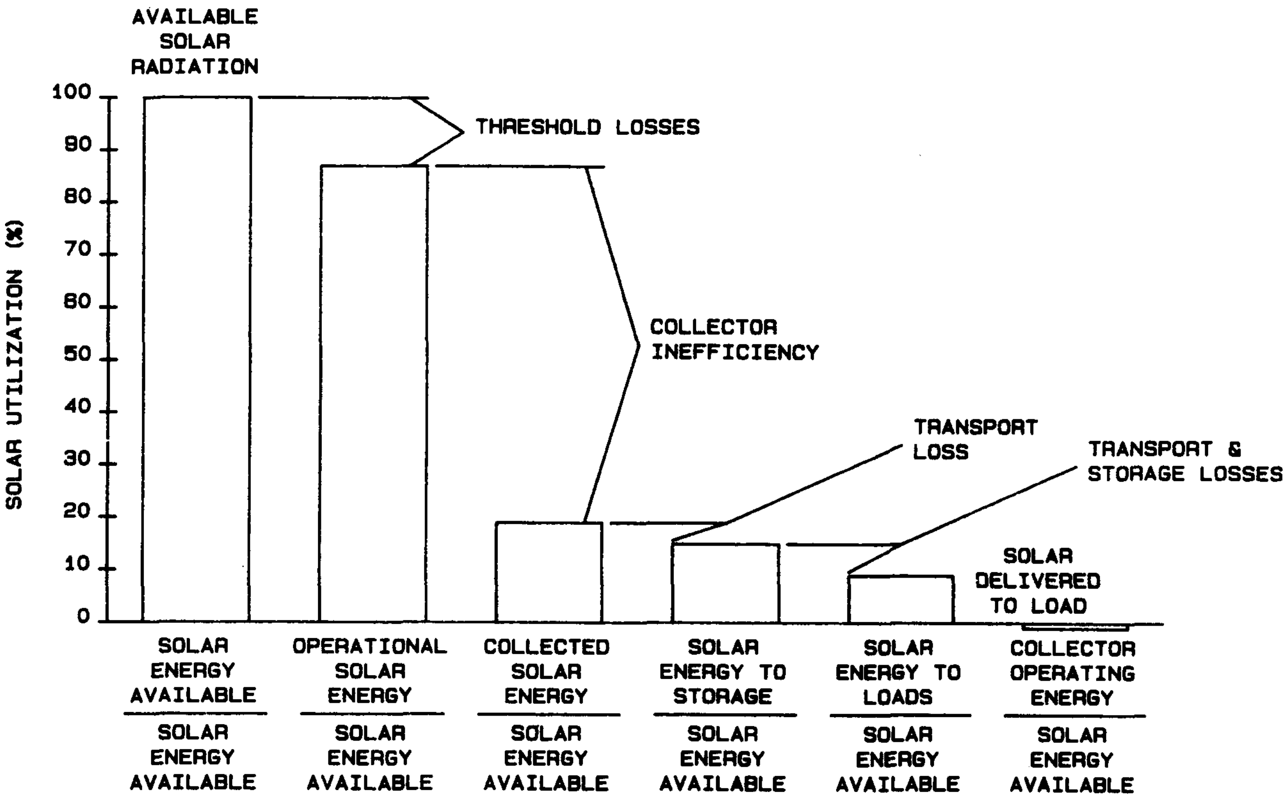

Figure 6. Solar Energy Use
San Anselmo School
April 1981 through March 1982

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 Report, November 1981, SOLAR/0004-80/18, Vitro Laboratories, Silver Spring, Maryland.

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

6. Solar Energy System Performance Evaluation, San Anselmo School, July 1980 through March 1981, SOLAR/2077-81/14, Vitro Laboratories, Silver Spring, Maryland.

7. Monthly Performance Report, San Anselmo School, April 1981, Vitro Laboratories, Silver Spring, Maryland.

8. Monthly Performance Report, San Anselmo School, May 1981, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, San Anselmo School, June 1981, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, San Anselmo School, July 1981, Vitro Laboratories, Silver Spring, Maryland.

11. Monthly Performance Report, San Anselmo School, August 1981, Vitro Laboratories, Silver Spring, Maryland.

12. Monthly Performance Report, San Anselmo School, September 1981, Vitro Laboratories, Silver Spring, Maryland.

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

13. Monthly Performance Report, San Anselmo School, October 1981, Vitro Laboratories, Silver Spring, Maryland.

14. Monthly Performance Report, San Anselmo School, November 1981, Vitro Laboratories, Silver Spring, Maryland.

15. Monthly Performance Report, San Anselmo School, December 1981, Vitro Laboratories, Silver Spring, Maryland.

16. Monthly Performance Report, San Anselmo School, January 1982, Vitro Laboratories, Silver Spring, Maryland.

17. Monthly Performance Report, San Anselmo School, February 1982, Vitro Laboratories, Silver Spring, Maryland.

18. Monthly Performance Report, San Anselmo School, March 1982, Vitro Laboratories, Silver Spring, Maryland.

APPENDIX A

SYSTEM DESCRIPTION

The San Anselmo School is a one-story, brick elementary school, located in San Jose, California. The building contains approximately 34,000 square feet of floor area, and is entirely bound by brick walls except for a small portion of window area. The school is functional all year-round and typically operates between the hours of 8:00 a.m. to 3:00 p.m. on weekdays. The school is usually unoccupied on the weekends.

The solar energy system was added to the existing building and is interconnected to the original cooling and heating equipment. The system was designed to supply 70% of the annual space heating requirements and 72% of the annual space cooling needs for the school.

The solar energy system incorporates 3,740 square feet of evacuated tubular glass collectors, a heat rejector, an expansion tank, a storage tank, a solar-operated absorption chiller, electronic controls, and interconnecting pipelines and hardware between the solar system and original heating and cooling equipment. Existing equipment was unaltered except for controls. These components include two gas-fired absorption chillers, two gas-fired absorption chiller/heaters, a cooling tower, 33 air-handling units, heating/cooling coils, and five pumps.

The collector array faces due south at a tilt of 40 degrees to the horizontal for collecting solar energy. The collector subsystem utilizes city water as a transfer medium from collector to storage and back to the collector again to complete the cycle. If solar energy is excessive, then solar energy is dissipated to the environment via a water-to-air heat rejector. When sufficiently high temperature is reached in the storage tank, hot water is either transferred to the solar chiller during the cooling mode, or is transferred directly to the heating coils during the heating mode. If solar energy is insufficient in meeting the space cooling and heating requirements, then two auxiliary gas-fired absorption chillers and two auxiliary gas-fired absorption chiller/heaters will satisfy the energy demand for the school.

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

Equipment/Component	Manufacturer	Model No.
Evacuated-Tube Collectors	General Electric	TC-100
Heat Rejector	McQuay-Perfex, Inc.	LHD-217 CH
Outdoor Storage Tank	Ace Buehler, Inc.	VS72-9A
Auxiliary Absorption Chiller and Chiller/Heaters	ARKLA Corporation	DFE300-600
Solar Absorption Chiller	ARKLA Corporation	WFB-300
Valves	Barber Colman	
Controllers	Barber Colman	

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

Mode 1 - Collector Freeze Protection - This mode occurs when the outside ambient temperature is below 43°F and the level of insolation is not sufficient for energy collection. Solar pump P8 is activated and valve V3 is opened to allow flow through the heat rejector. Energy from the storage tank maintains the water in the collector loop at 38°F via modulating valve V2. This prevents all equipment from being damaged by freezing.

Mode 2 - Auxiliary Collector Freeze Protection - This is a safety backup freeze protection mode. If the temperature exiting the collectors drops below 34°F, then dump valve V4 directs city water through the collector loop to prevent the collectors from freezing.

Mode 3 - Solar Energy Collection - Solar energy collection is activated whenever insolation levels are sufficient. Pump P8 is turned on and all the flow bypasses the storage tank and returns to the collectors to complete the cycle. Pump P8 is deactivated when insolation levels fall below the set point.

Mode 4 - Collector-to-Storage - This mode occurs when the temperature exiting the collectors is 175°F or above. This closes the bypass port on valve V2 and allows all water to flow through storage. When the temperature falls below 175°F, valve V2 reverses position and allows all water to bypass the storage tank. This assures a positive energy storage into the tank.

Mode 5 - Storage-to-Space Cooling - Whenever space cooling is required and the temperature in the storage tank is above 175°F, then pump P7 is activated, allowing flow from storage to the solar-operated absorption chiller. If solar energy is insufficient to meet the cooling demand, then two auxiliary gas-fired absorption chillers and two auxiliary gas-fired absorption chiller/heaters will supply the space cooling requirements.

Mode 6 - Storage-to-Space Heating - Whenever space heating is required and there is sufficient energy in the storage tank, then pump P7 is activated, allowing hot water to flow to the heating coils for distribution to the heating zones via the air-handling units. If solar energy is insufficient, then two auxiliary gas-fired absorption chiller/heaters will supply the remaining heating requirements.

Mode 7 - Solar Heat Rejection - This mode occurs when excess solar energy is diverted from the collectors to the heat rejector unit via valve V3. This mode operates when the temperature exiting the collectors is 220°F or above to reject excess energy to the environment. This deactivates when the temperature exiting the collectors falls below 220°F.

Mode 8 - Auxiliary Heat Protection - This is a safety backup protection to prevent collector damage. This mode activates when the temperature leaving the collectors exceeds 240°F and opens dump valve V4 to allow city water to cool the collectors. This mode deactivates when the water leaving the collectors falls below 232°F.

Mode 9 - Power Failure Protection - This mode activates at any time during a power failure. Dump valve V4 opens to allow city water to the collector loop and remains open until power is restored.

NOTE: An absorption chiller/heater is an absorption chiller which can be utilized for space heating by deactivating the cooling tower flow.

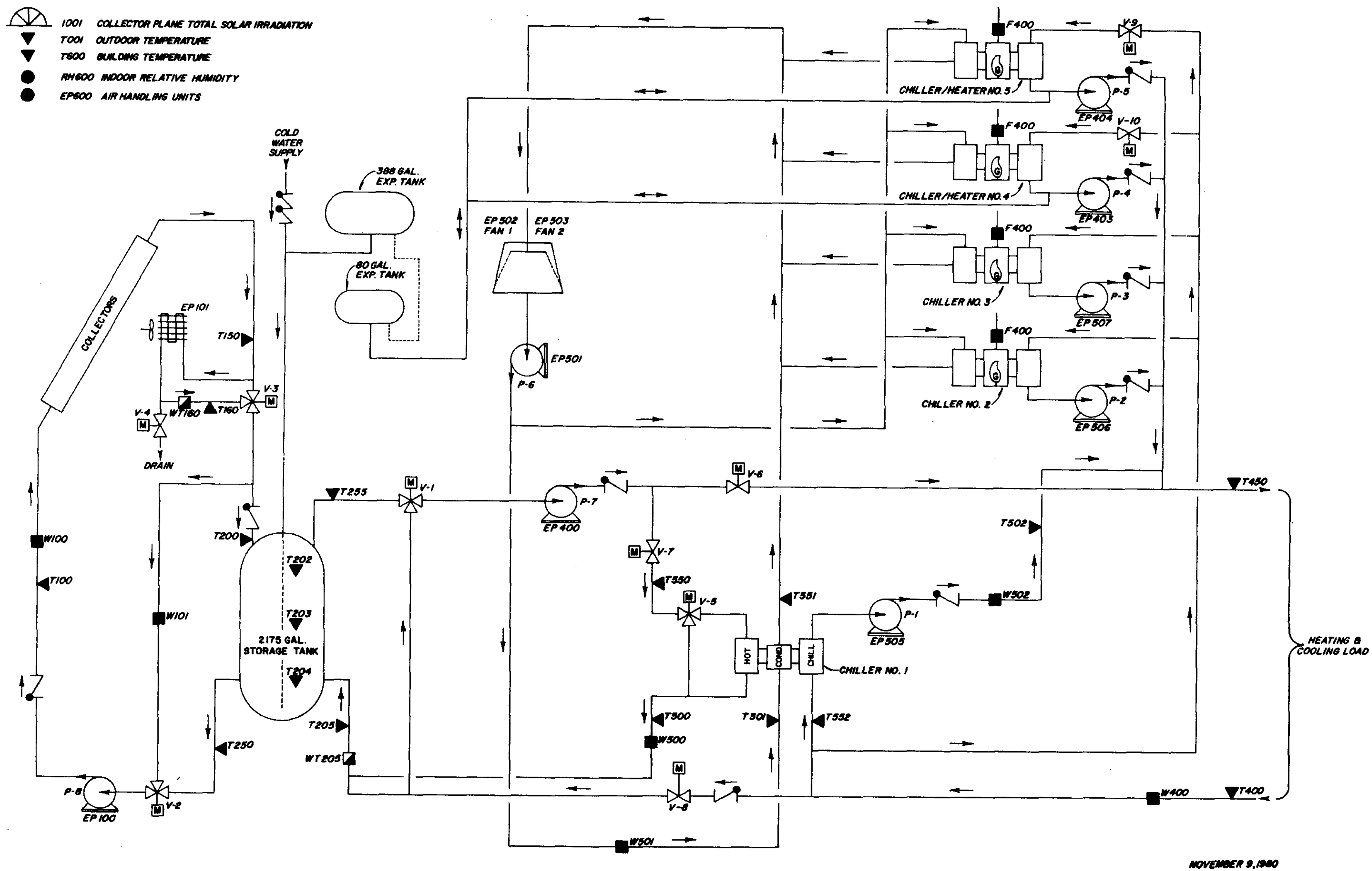

Figure A-1. San Anselmo School Solar Energy System Schematic

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

The performance of the San Anselmo School 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.

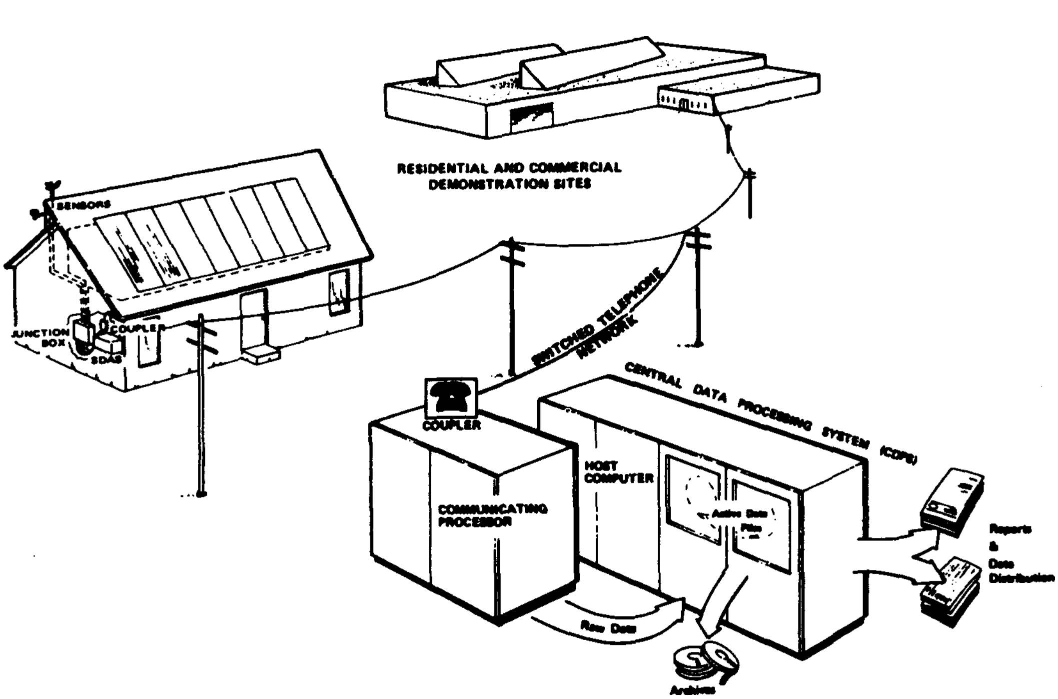

Figure B-1. The National Solar Data Network

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 San Anselmo School solar energy system from April 1981 through March 1982 was analyzed and Monthly Performance Reports were prepared. See the following page for a list of these reports.

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

OTHER DATA REPORTS ON THIS SITE

Monthly Performance Reports:

*July 1980, SOLAR/2077-80/07
*August 1980, SOLAR/2077-80/08
*September 1980, SOLAR/2077-80/09
*November 1980, SOLAR/2077-80/11
*December 1980, SOLAR/2077-80/12
*January 1981, SOLAR/2077-81/01
March 1981
April 1981
May 1981
June 1981
July 1981
August 1981
September 1981
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November 1981
December 1981
January 1982
February 1982
March 1982

*Solar Energy System Performance Evaluation

SOLAR/2077-81/14

* 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

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

* Primary Performance Factors

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

* Primary Performance Factors

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

* Primary Performance Factors

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

* Primary Performance Factors

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

* Primary Performance Factors

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

* Primary Performance Factors

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

* Primary Performance Factors

SECTION 2. SOLAR TERMINOLOGY

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

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

Energy Savings — The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.

Expansion Tank — A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as the system heat transfer fluid expands and contracts to prevent excessive pressure from developing and causing damage.

F-Curve — The collector instantaneous efficiency curve. Used in the "F-curve" procedure for collector analysis (see Instantaneous Efficiency).

Fixed Collector — A solar collector that is fixed in position and cannot be rotated to follow the sun daily or seasonably.

Flat-Plate Collector — A solar energy collecting device consisting of a relatively thin panel of absorbing material. A container with insulated bottom and sides and covered with one or more covers transparent to visible solar energy and relatively opaque to infrared energy. Visible energy from the sun enters through the transparent cover and raises the temperature of the absorbing panel. The infrared energy re-radiated from the panel is trapped within the collector because it cannot pass through the cover. Glass is an effective cover material (see Selective Surface).

Focusing Collector — A concentrating type collector using parabolic mirrors or optical lenses to focus the energy from a large area onto a small absorbing area.

Fossil Fuel — Petroleum, coal, and natural gas derived fuels.

Glazing — In solar/energy technology, the transparent covers used to reduce energy losses from a collector panel.

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

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

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

SECTION 3. GENERAL ACRONYMS

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

APPENDIX D

PERFORMANCE EQUATIONS

SAN ANSELMO SCHOOL

INTRODUCTION

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

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

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

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

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

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

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

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

For a liquid system ΔH is generally given by

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

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

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* See Appendix B.

For an air system ΔH is generally given by

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

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

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

For electrical power, a general example is

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

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

Letter Designations

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

Subsystem Designations Number Sequence	Subsystem/Data Group
001 to 099	Climatological
100 to 199	Collector and Heat Transport
200 to 299	Thermal Storage
300 to 399	Hot Water
400 to 499	Space Heating
500 to 599	Space Cooling
600 to 699	Building/Load

EQUATIONS USED TO GENERATE MONTHLY PERFORMANCE VALUES

WEATHER DATA

AVERAGE AMBIENT TEMPERATURE (^{o}F)

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

AVERAGE BUILDING TEMPERATURE (^{o}F)

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

DAYTIME AVERAGE AMBIENT TEMPERATURE (^{o}F)

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

for ± three hours from solar noon

BUILDING RELATIVE HUMIDITY (%)

$$RELH = (1/60) \times \Sigma\ RH600 \times \Delta\tau$$

COLLECTOR SUBSYSTEM

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

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

OPERATIONAL INCIDENT SOLAR ENERGY (BTU)

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

when the collector loop is activated

SOLAR ENERGY COLLECTED BY THE ARRAY (BTU)

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

REJECTED SOLAR ENERGY (BTU)

$$CSRJE = \Sigma\ [M160 \times CP \times (T150 - T160)] \times \Delta\tau$$

when rejector fan is activated

INCIDENT SOLAR ENERGY ON COLLECTOR ARRAY (BTU)

$$SEA = CLAREA \times SE$$

COLLECTED SOLAR ENERGY (BTU/ft^2)

$$SEC = SECA/CLAREA$$

COLLECTOR ARRAY EFFICIENCY

$$CLEF = SECA/SEA$$

COLLECTOR ARRAY OPERATIONAL EFFICIENCY

$$CLEFOP = SECA/SEOP$$

ECSS OPERATING ENERGY (BTU)

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

STORAGE SUBSYSTEM

AVERAGE TEMPERATURE OF STORAGE (^oF)

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

SOLAR ENERGY TO STORAGE (BTU)

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

SOLAR ENERGY FROM STORAGE (BTU)

$$STEO = \Sigma\ [M205 \times CP \times (T255 - T205)] \times \Delta\tau$$

CHANGE IN STORED ENERGY (BTU)

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

$$STECH = STECH1 - STECH1_p$$

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

TST1 = last hourly storage temperature

STORAGE EFFICIENCY (%)

STEFF = (STECH + STEO)/STEI x 100

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

STPER = (1/60) x Σ [SUR_AREA x (TST - AMB)] x Δτ

SUR_AREA = storage tank surface area

ABM = temperature surrounding storage tank

SPACE HEATING SUBSYSTEM

SPACE HEATING SOLAR-UNIQUE OPERATING ENERGY (BTU)

HOPE1 = [56.8833 x EP400] x Δτ

in heating mode

SPACE HEATING SUBSYSTEM OPERATING ENERGY (BTU)

HOPE = [56.8833 x Σ (EP400 + EP403 + EP404 + EP600 + AUXP6 + AUXP7)] x Δτ

in heating mode

AUXP6 = Chiller #4 internal power

AUXP7 = Chiller #5 internal power

SOLAR ENERGY TO SPACE HEATING SUBSYSTEM (BTU)

HSE = Σ [M205 x CP x (T255 - T205)] x Δτ

in heating mode

SPACE HEATING AUXILIARY FOSSIL ENERGY (BTU)

HAF = Σ F400 x NGC

NGC = 1021 BTU/FT^3

in heating mode

SPACE HEATING AUXILIARY THERMAL ENERGY (BTU)

HAT = HAF x 0.6

SPACE HEATING LOAD (BTU)

CDE = Σ [M400 x CP x (T450 - T400)] x Δτ

EHL = CDE

in heating mode

SPACE HEATING SOLAR FRACTION (PERCENT)

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

SPACE HEATING FOSSIL SAVINGS (BTU)

$$HSVF = HSE/0.6$$

SPACE HEATING ELECTRICAL SAVINGS

$$HSVE = -HOPE\ 1$$

SPACE COOLING SUBSYSTEM

SPACE COOLING OPERATING ENERGY (BTU)

$$COPE = [56.8833 \times \Sigma\ (EP400 + EP403 + EP404 + EP501 + EP502 + EP503 + EP505 + EP506 + EP507 + EP600 + AUXP1 + AUXP2 + AUXP3 + AUXP4 + AUXP5)] \times \Delta\tau$$

in cooling mode

AUXP1 = Chiller #1 internal power (solar chiller)

AUXP2 = Chiller #2 internal power

AUXP3 = Chiller #3 internal power

AUXP4 = Chiller #4 internal power

AUXP5 = Chiller #5 internal power

SPACE COOLING - SOLAR UNIQUE OPERATING ENERGY (BTU)

$$COPE1 = [56.8833 \times TCEL/CL \times \Sigma\ (EP501 + EP502 + EP503)] \times \Delta\tau + 56.8833 \times \Sigma(EP400 + EP505 + AUXP1) \times \Delta\tau$$

SPACE COOLING AUX FOSSIL ENERGY (BTU)

$$CAF = \Sigma F400 \times NGC$$

in cooling mode

SPACE COOLING AUXILIARY THERMAL ENERGY (BTU)

$$CAT = CAF \times 0.6$$

SOLAR ENERGY TO SPACE COOLING SUBSYSTEM (BTU)

$$CSE = \Sigma\ [M500 \times CP \times (T550 - T500)] \times \Delta\tau$$

SPACE COOLING LOAD (BTU)

$$CL = \Sigma\ [M400 \times CP \times (T400 - T450)] \times \Delta\tau$$

in cooling mode

SPACE COOLING SOLAR FRACTION (%)

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

SPACE COOLING FOSSIL SAVINGS (BTU)

$$CSVF = CSE/0.6$$

SPACE COOLING ELECTRICAL SAVINGS (BTU)

$$CSVE = -COPE1$$

<u>THERMODYNAMIC CONVERSION EQUIPMENT</u> (SOLAR-UNIQUE CHILLER)

TCE EQUIPMENT LOAD (BTU)

$$TCEL = \Sigma\ [M502 \times CP \times (T552 - T502)] \times \Delta\tau$$

TCE INPUT ENERGY (BTU)

$$TCEI = CSE$$

TCE REJECTED ENERGY (BTU)

$$TCERJE = \Sigma\ [M501 \times CP \times (T551 - T501)] \times \Delta\tau$$

TCE OPERATING ENERGY (BTU)

$$TCEOPE = COPE1$$

TCE CHILLER COP

$$TCECOP = TCEL/TCEI$$

<u>AUXILIARY THERMODYNAMIC CONVERSION EQUIPMENT (ATCE)</u> (AUXILIARY CHILLERS)

ATCE EQUIPMENT LOAD (BTU)

$$ATCEL = CL - TCEL$$

ATCE THERMAL INPUT ENERGY (BTU)

ATCEI = CAT

ATCE REJECTED ENERGY (BTU)

ATCERJE = ATCEI + ATCEL

ATCE OPERATING ENERGY (BTU)

$$ATCEOPE = [56.8833 \times ATCEL/CL \times \Sigma\ (EP501 + EP502 + EP503)] \times \Delta\tau + [56.8833 \times \Sigma\ (EP403 + EP404 + EP506 + EP507 + AUXP2 + AUXP3 + AUXP4 + AUXP5)] \times \Delta\tau$$

ATCE CHILLERS COP

ATCECOP = ATCEL/ATCEI

SYSTEM FACTORS

ENERGY TO LOADS

CSEO = CSE + HSE

SOLAR ENERGY USED

SEL = CSEO

ECSS SOLAR CONVERSION EFFICIENCY

CSCEF = SEL/SEA

SYSTEM LOAD

SYSL = CL + EHL

SYSTEM SOLAR FRACTION

SFR = (CSFR x CL + HSFR x EHL)/SYSL

SYSTEM OPERATING ENERGY

SYSOPE = CSOPE + COPE + HOPE

SYSTEM AUXILIARY FOSSIL ENERGY

$AXF = \Sigma\ F400 \times NGC$

SYSTEM AUXILIARY THERMAL ENERGY

AXT = HAT + CAT

SYSTEM ELECTRICAL SAVINGS

TSVE = HSVE + CSVE - CSOPE

SYSTEM FOSSIL SAVINGS

TSVF = HSVF + CSVF

TOTAL ENERGY CONSUMED

TECSM = SECA + SYSOPE + AXF

SYSTEM PERFORMANCE FACTOR

SYSPF = SYSL/(AXF + 3.33 x SYSOPE)

SAN ANSELMO SCHOOL LONG-TERM WEATHER DATA

COLLECTOR TILT: 40 DEGREES
LATITUDE: 37 DEGREES

LOCATION: SAN JOSE, CALIFORNIA
COLLECTOR AZIMUTH: 0 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1469.	708.	0.48195	1.656	1172.	481	0	50.
FEB	1922.	1018.	0.52947	1.438	1463.	350	0	53.
MAR	2496.	1456.	0.58341	1.214	1768.	322	0	55.
APR	3079.	1921.	0.62389	1.012	1944.	228	12	58.
MAY	3477.	2212.	0.63622	0.882	1952.	123	20	62.
JUN	3634.	2349.	0.64623	0.829	1947.	50	71	66.
JUL	3549.	2323.	0.65442	0.851	1978.	12	117	68.
AUG	3227.	2054.	0.63643	0.953	1958.	15	111	68.
SEP	2702.	1700.	0.62895	1.135	1929.	13	94	68.
OCT	2087.	1213.	0.58118	1.378	1671.	90	19	63.
NOV	1573.	822.	0.52263	1.620	1332.	276	0	56.
DEC	1343.	645.	0.48036	1.740	1123.	456	0	50.

LEGEND:

HOBAR ==> MONTHLY AVERAGE DAILY EXTRATERRESTRIAL RADIATION (IDEAL) IN BTU/DAY-FT2.
HBAR ==> MONTHLY AVERAGE DAILY RADIATION (ACTUAL) IN BTU/DAY-FT2.
KBAR ==> RATIO OF HBAR TO HOBAR.
RBAR ==> RATIO OF MONTHLY AVERAGE DAILY RADIATION ON TILTED SURFACE TO THAT ON A HORIZONTAL SURFACE FOR EACH MONTH (I.E., MULTIPLIER OBTAINED BY TILTING).
SBAR ==> MONTHLY AVERAGE DAILY RADIATION ON A TILTED SURFACE (I.E., RBAR * HBAR) IN BTU/DAY-FT2.
HDD ==> NUMBER OF HEATING DEGREE DAYS PER MONTH.
CDD ==> NUMBER OF COOLING DEGREE DAYS PER MONTH.
TBAR ==> AVERAGE AMBIENT TEMPERATURE IN DEGREES FAHRENHEIT.

APPENDIX F

CONVERSION FACTORS

Energy Conversion Factors

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

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

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

APPENDIX G

SENSOR TECHNOLOGY

Temperature Sensors

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

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

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

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

WIND SENSOR

Wind speed and direction are measured by a WeatherMeasure W102-P-DC/540 or [illegible]1-P-DC/540 wind sensor. Wind speed is measured by means of a four-bladed propeller coupled to a DC generator.

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

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

HUMIDITY SENSORS

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

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

INSOLATION SENSORS

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

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

LIQUID FLOW SENSORS (NON-TOTALIZING)

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

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

LIQUID FLOW SENSORS (TOTALIZING)

Hersey Series 400 flow meters are used to measure totalized liquid flow. The meter is a nutating disk, positive displacement type meter. An R-15 register with an SPDT reed switch is used to provide an output to the data acquisition subsystem.

The output of the reed switch is input to a Martin DR-1 Digital Ramp which counts the number of pulses and produces a zero to five volt analog signal corresponding to the pulse count.

Materials:	Meter body	- bronze
	Measuring chamber	- plastic
Accuracy:	± 1.5%	

AIR FLOW SENSORS

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

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

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

FUEL OIL FLOW SENSOR

The Kent Mini-Major is used as a flow oil flow meter. The meter utilizes an oscillating piston as a positive displacement element. The oscillating piston is connected to a pulser which sends pulses to the Site Data Acquisition Subsystem for totalization.

Operating Temperature:	100°C (max)
Flow Range:	0.6 to 48 gph
Accuracy:	± 1% of full scale

FUEL GAS FLOW SENSOR

The American AC-175 gas meter is used for the measurement of totalized fuel gas flow. The drop in pressure between the inlet and outlet of the meter is responsible for the action of the meter. The principle of measurement is positive displacement. Four chambers in the meter fill and empty in sequence. The exact volume of compartments is known, so by counting the number of displacements the volume is measured. Sliding control valves control the entrance and exit of the gas to the compartments. The meter is temperature compensated to reference all volumetric readings to 60°F.

Rated Capacity:	175 cubic ft/hr
Max Working Pressure:	5 psi

ELECTRIC POWER SENSORS

Ohio Semitronics Series PC5 wattmeters are used as electric power sensors. They utilize Hall effect devices as multipliers taking the product of the instantaneous voltage and current readings to determine the electrical power. This technique automatically takes power factor into consideration and produces a true power reading.

Power Factor Range:	1 to 0 (lead or lag)
Response Time:	250 ms
Temperature Effect:	1% of reading
Accuracy:	0.5% of full scale

HEAT FLUX SENSORS

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

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

MONTHLY REPORT: APRIL 1981
SITE SUMMARY: SAN ANSELMO SCHOOL

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	209.642 MILLION BTU
	56054 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	47.626 MILLION BTU
	12734 BTU/SQ.FT.
PERCENT OF COLLECTED TO LOADS	48 PERCENT
COLLECTOR ARRAY EFFICIENCY	0.227
COLLECTOR ARRAY OPERATIONAL EFFICIENCY	0.228
AVERAGE AMBIENT TEMPERATURE	59 DEGREES F
AVERAGE BUILDING TEMPERATURE	73 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.11
ECSS OPERATING ENERGY	1.358 MILLION BTU
ECSS PERFORMANCE FACTOR	6065 BTU/SQ.FT.
TOTAL SYSTEM OPERATING ENERGY	24.149 MILLION BTU
TOTAL ENERGY CONSUMED	257.959 MILLION BTU
SOLAR DELIVERED/BUILDING AREA	667 BTU/SQ.FT.
AUXILIARY USED/BUILDING AREA	3041 BTU/SQ.FT.

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	1.637	32.483	34.120 MILLION BTU
SOLAR FRACTION	N.A.	85	29	32 PERCENT
SOLAR SAVINGS RATIO	N.A.	2.778	0.150	0.598
SOLAR ENERGY USED	N.A.	6.680	16.002	22.682 MILLION BTU
OPERATING ENERGY	N.A.	1.995	20.796	24.149 MILLION BTU
AUX. THERMAL ENERGY	N.A.	1.372	102.029	103.401 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	2.286	170.048	186.094 MILLION BTU
ELECTRICAL SAVINGS	N.A.	-0.033	-1.480	-2.871 MILLION BTU
FOSSIL SAVINGS	N.A.	11.134	26.670	37.803 MILLION BTU

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 4.83

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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MONTHLY REPORT: APRIL 1981

SITE SUMMARY: SAN ANSELMO SCHOOL

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	209.642 MILLION BTU
	56054 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	47.626 MILLION BTU
	12734 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	59 DEGREES F
AVERAGE BUILDING TEMPERATURE	73 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.11
ECSS OPERATING ENERGY	1.358 MILLION BTU
STORAGE EFFICIENCY	73.93 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	0.519 BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	24.149 MILLION BTU
TOTAL ENERGY CONSUMED	257.959 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	1.637	32.483	34.120 MILLION BTU
SOLAR FRACTION	N.A.	85	29	32 PERCENT
SOLAR ENERGY USED	N.A.	6.680	16.002	22.682 MILLION BTU
OPERATING ENERGY	N.A.	1.995	20.796	24.149 MILLION BTU
AUX. THERMAL ENERGY	N.A.	1.372	102.029	103.401 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	N.A.	2.286	170.048	186.094 MILLION BTU
ELECTRICAL SAVINGS	N.A.	-0.033	-1.480	-2.871 MILLION BTU
FOSSIL SAVINGS	N.A.	11.134	26.670	37.803 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.13

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 4.83

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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MONTHLY REPORT: APRIL 1981
SITE SUMMARY: SAN ANSELMO SCHOOL

GENERAL SITE DATA:	SI UNITS
INCIDENT SOLAR ENERGY	221.172 GIGA JOULES
	636550 KJ/SQ.M.
COLLECTED SOLAR ENERGY	50.245 GIGA JOULES
	144610 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	15 DEGREES C
AVERAGE BUILDING TEMPERATURE	23 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.11
ECSS OPERATING ENERGY	1.433 GIGA JOULES
STORAGE EFFICIENCY	73.93 PERCENT
EFFECTIVE HEAT TRANSFER COEFFFICIENT	2.946 W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	25.477 GIGA JOULES
TOTAL ENERGY CONSUMED	272.147 GIGA JOULES

SUBSYSTEM SUMMARY:	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	N.A.	1.727	34.270	35.997 GIGA JOULES
SOLAR FRACTION	N.A.	85	29	32 PERCENT
SOLAR ENERGY USED	N.A.	7.048	16.882	23.930 GIGA JOULES
OPERATING ENERGY	N.A.	2.104	21.940	25.477 GIGA JOULES
AUX. THERMAL ENG	N.A.	1.447	107.640	109.088 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	N.A.	2.412	179.401	196.329 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	-0.035	-1.561	-3.028 GIGA JOULES
FOSSIL SAVINGS	N.A.	11.746	28.136	39.883 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.13
INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 4.83

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

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, JUNE 1980.
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ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	6.757	56	0.656	N	0.053	0.124	0.097
2	7.636	54	0.571	O	0.055	0.000	0.075
3	8.218	54	0.886	T	0.053	0.000	0.108
4	8.143	59	0.000		0.052	0.669	0.000
5	8.074	63	0.000	A	0.049	1.127	0.000
6	7.711	57	1.909	P	0.048	0.000	0.248
7	7.836	56	1.268	P	0.055	0.002	0.162
8	7.960	54	1.251	L	0.054	0.000	0.157
9	7.907	55	1.379	I	0.054	0.000	0.174
10	8.042	52	1.296	C	0.059	0.000	0.161
11	8.105	51	0.000	A	0.058	0.286	0.000
12	8.118	54	0.000	B	0.060	1.017	0.000
13	8.094	60	1.823	L	0.050	0.000	0.225
14	7.721	61	0.000	E	0.055	0.617	0.000
15	7.530	58	0.000		0.050	0.924	0.000
16	6.895	62	0.000		0.050	0.883	0.000
17	5.633	59	0.000		0.026	0.573	0.000
18	0.606	53	0.000		0.004	0.000	0.000
19	1.879	52	0.000		0.022	0.000	0.000
20	6.631	58	1.024		0.053	0.002	0.154
21	7.425	60	1.151		0.049	0.000	0.155
22	7.746	69	1.276		0.038	0.000	0.165
23	7.352	68	1.464		0.032	0.000	0.199
24	7.318	60	1.095		0.036	0.000	0.150
25	3.837	55	0.000		0.036	0.000	0.000
26	6.503	55	0.000		0.054	0.001	0.000
27	7.745	61	1.359		0.048	0.000	0.176
28	7.735	72	1.457		0.040	0.000	0.188
29	7.380	79	1.369		0.032	0.000	0.186
30	7.107	73	1.447		0.032	0.000	0.204
SUM	209.642	-	22.682	N.A.	1.358	6.224	-
AVG	6.988	59	0.756	N.A.	0.045	0.207	0.108
PFRV	0.9694	0.9694	0.9694	N.A.	0.9694	0.9694	0.9694

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

MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)	OPERATIONAL COLLECTOR SUBSYSTEM EFFICIENCY
1	6.757	6.718	1.512	59	0.224	0.225
2	7.636	7.623	1.792	63	0.235	0.235
3	8.218	8.218	2.102	67	0.256	0.256
4	8.143	8.143	1.763	73	0.216	0.216
5	8.074	8.074	1.671	79	0.207	0.207
6	7.711	7.711	2.015	69	0.261	0.261
7	7.836	7.836	1.981	69	0.253	0.253
8	7.960	7.960	1.971	65	0.248	0.248
9	7.907	7.907	2.014	68	0.255	0.255
10	8.042	8.042	2.009	64	0.250	0.250
11	8.105	8.105	1.539	62	0.190	0.190
12	8.118	8.118	1.443	66	0.178	0.178
13	8.094	8.094	2.176	76	0.269	0.269
14	7.721	7.721	1.589	79	0.206	0.206
15	7.530	7.478	1.375	70	0.183	0.184
16	6.895	6.863	1.284	78	0.186	0.187
17	5.633	5.424	0.955	70	0.170	0.176
18	0.606	0.272	-0.005	55	-0.008	-0.019
19	1.879	1.777	0.066	57	0.035	0.037
20	6.631	6.631	1.547	67	0.233	0.233
21	7.425	7.389	1.898	72	0.256	0.257
22	7.746	7.746	2.083	83	0.269	0.269
23	7.352	7.352	1.920	86	0.261	0.261
24	7.318	7.233	1.696	72	0.232	0.234
25	3.837	3.707	0.509	63	0.133	0.137
26	6.503	6.503	1.037	63	0.159	0.159
27	7.745	7.745	1.812	73	0.234	0.234
28	7.735	7.735	1.941	87	0.251	0.251
29	7.380	7.380	2.081	95	0.282	0.282
30	7.107	7.107	1.851	90	0.260	0.260
SUM	209.642	208.612	47.626	-	-	-
AVG	6.988	6.954	1.588	71	0.227	0.228
PFRV	0.9694	0.9694	0.9694	0.9694	0.9694	0.9694

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

MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

STORAGE PERFORMANCE

DAY OF MONTH (NBS ID)	ENERGY TO STORAGE MILLION BTU (Q200)	ENERGY FROM STORAGE MILLION BTU (Q201)	CHANGE IN STORED ENERGY MILLION BTU (Q202)	STORAGE AVERAGE TEMP DEG F	EFFECTIVE HEAT TRANSFER COEFFICIENT BTU/DEG F/ SQ FT/HR
1	1.095	0.723	-0.074	148	0.83
2	1.631	0.652	-0.029	128	2.31
3	1.883	1.030	0.563	139	0.59
4	0.920	0.000	0.675	179	0.35
5	0.119	0.000	0.030	197	0.11
6	1.942	1.958	-0.656	163	1.03
7	1.875	1.475	0.002	148	0.73
8	1.845	1.421	0.016	151	0.71
9	1.860	1.451	0.013	150	0.71
10	1.770	1.483	0.010	152	0.47
11	0.857	0.000	0.634	177	0.30
12	0.181	0.000	0.075	196	0.13
13	2.065	1.988	-0.616	162	1.15
14	0.783	0.000	0.608	179	0.25
15	0.227	0.000	0.068	197	0.20
16	0.205	0.000	0.054	199	0.19
17	0.202	0.000	0.029	200	0.21
18	0.000	0.000	-0.256	191	0.32
19	-0.102	0.000	-0.246	176	0.20
20	1.260	0.950	-0.123	153	0.77
21	1.788	1.319	0.006	152	0.85
22	2.128	1.674	0.170	164	0.51
23	1.703	1.859	-0.209	162	0.10
24	1.432	1.212	0.039	156	0.32
25	0.334	0.000	0.111	160	0.36
26	0.701	0.000	0.461	179	0.33
27	1.461	1.782	-0.582	161	0.45
28	1.672	1.530	-0.006	154	0.31
29	2.144	1.632	0.223	160	0.61
30	1.721	1.777	-0.157	161	0.19
SUM	35.702	25.916	0.480	-	-
AVG	1.190	0.864	0.016	166	0.52
PFRV	0.9694	0.9694	N.A.	0.9694	0.9694

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

MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

SPACE HEATING SUBSYSTEM I

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	CONTROLLED DELIVERED ENERGY MILLION BTU	TOTAL SOLAR ENERGY USED MILLION BTU (Q400)	TOTAL AUXILIARY THERMAL USED MILLION BTU (Q401)	SOLAR FRACTION OF LOAD PCT (N400)	ELECT ENERGY SAVINGS MILLION BTU (Q415)	FOSSIL ENERGY SAVINGS MILLION BTU (Q417)	BLDG TEMP DEG F (N406)	AMB TEMP DEG. F (N113)
1	0.082	0.082	0.317	0.037	49	-0.006	0.528	74	56
2	0.392	0.392	0.000	1.167	0	0.000	0.000	73	54
3	0.102	0.102	0.375	0.027	100	-0.001	0.625	73	54
4	0.000	0.000	0.000	0.000	0	0.000	0.000	71	59
5	0.000	0.000	0.000	0.000	0	0.000	0.000	69	63
6	0.263	0.263	0.861	0.000	100	-0.006	1.435	72	57
7	0.411	0.411	0.574	0.000	100	-0.001	0.956	73	56
8	0.083	0.083	0.527	0.000	100	-0.001	0.878	73	54
9	0.085	0.085	0.533	0.000	100	-0.001	0.889	74	55
10	0.000	0.000	0.443	0.000	0	-0.001	0.738	74	52
11	0.000	0.000	0.000	0.000	0	0.000	0.000	70	51
12	0.000	0.000	0.000	0.000	0	0.000	0.000	68	54
13	0.111	0.111	1.061	0.000	100	-0.009	1.768	71	60
14	0.000	0.000	0.000	0.000	0	0.000	0.000	72	61
15	0.000	0.000	0.000	0.000	0	0.000	0.000	73	58
16	0.000	0.000	0.000	0.000	0	0.000	0.000	73	62
17	0.000	0.000	0.000	0.000	0	0.000	0.000	71	59
18	0.000	0.000	0.000	0.000	0	0.000	0.000	69	53
19	0.000	0.000	0.000	0.000	0	0.000	0.000	67	52
20	0.043	0.043	0.708	0.048	95	-0.003	1.179	71	58
21	0.134	0.134	0.511	0.000	100	-0.001	0.852	75	60
22	0.000	0.000	0.000	0.000	0	0.000	0.000	79	69
23	-0.012	-0.012	0.000	0.000	0	0.000	0.000	80	68
24	0.000	0.000	0.124	0.000	0	0.000	0.207	78	60
25	0.000	0.000	0.000	0.000	0	0.000	0.000	74	55
26	0.000	0.000	0.000	0.000	0	0.000	0.000	70	55
27	0.000	0.000	0.449	0.000	42618	-0.001	0.748	73	61
28	0.000	0.000	0.128	0.000	0	0.000	0.213	77	72
29	-0.057	-0.057	0.070	0.093	0	0.000	0.117	82	79
30	0.000	0.000	0.000	0.000	0	0.000	0.000	84	73
SUM	1.637	1.637	6.680	1.372	-	-0.033	11.134	-	-
AVG	0.055	0.055	0.223	0.046	85	-0.001	0.371	73	59
PFRV	0.9694	0.9694	0.9694	0.9639	0.9639	0.9694	0.9694	0.9694	0.9694

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MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

SPACE HEATING SUBSYSTEM II

DAY OF MONTH (NBS ID)	SPACE HEATING LOAD MILLION BTU (Q402)	MEASURED SOLAR ENERGY USED MILLION BTU	SOLAR ENERGY LOSSES TO LOAD MILLION BTU	TOTAL OPERATING ENERGY MILLION BTU (Q403)	SOLAR SPECIFIC OPERATING ENERGY MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q410)	HEATING DEGREE DAYS
1	0.082	0.317	0.000	0.096	0.006	N	0.062	10
2	0.392	0.000	0.000	0.152	0.000	O	1.945	10
3	0.102	0.375	0.000	0.115	0.001	T	0.045	9
4	0.000	0.000	0.000	0.090	0.000		0.000	5
5	0.000	0.000	0.000	0.086	0.000	A	0.000	2
6	0.263	0.861	0.000	0.055	0.006	P	0.000	7
7	0.411	0.574	0.000	0.066	0.001	P	0.000	5
8	0.083	0.527	0.000	0.065	0.001	L	0.000	10
9	0.085	0.533	0.000	0.062	0.001	I	0.000	8
10	0.000	0.443	0.000	0.064	0.001	C	0.000	12
11	0.000	0.000	0.000	0.099	0.000	A	0.000	15
12	0.000	0.000	0.000	0.104	0.000	B	0.000	10
13	0.111	1.061	0.000	0.074	0.009	L	0.000	5
14	0.000	0.000	0.000	0.093	0.000	E	0.000	2
15	0.000	0.000	0.000	0.085	0.000		0.000	5
16	0.000	0.000	0.000	0.086	0.000		0.000	2
17	0.000	0.000	0.000	0.044	0.000		0.000	3
18	0.000	0.000	0.000	0.006	0.000		0.000	11
19	0.000	0.000	0.000	0.037	0.000		0.000	13
20	0.043	0.708	0.000	0.072	0.003		0.080	8
21	0.134	0.511	0.000	0.055	0.001		0.000	5
22	0.000	0.000	0.000	0.028	0.000		0.000	0
23	-0.012	0.000	0.000	0.014	0.000		0.000	17
24	0.000	0.124	0.000	0.023	0.000		0.000	4
25	0.000	0.000	0.000	0.062	0.000		0.000	6
26	0.000	0.000	0.000	0.091	0.000		0.000	10
27	0.000	0.449	0.000	0.118	0.001		0.000	4
28	0.000	0.128	0.000	0.016	0.000		0.000	0
29	-0.057	0.070	0.000	0.030	0.000		0.155	0
30	0.000	0.000	0.000	0.005	0.000		0.000	0
SUM	1.637	6.680	0.000	1.995	0.033	N.A.	2.286	197
AVG	0.055	0.223	0.000	0.066	0.001	N.A.	0.076	7
PFRV	0.9694	0.9694	0.9750	0.9694	0.9694	N.A.	0.9639	N.A.

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MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

SPACE COOLING SUBSYSTEM

DAY OF MONTH (NBS ID)	SPACE COOLING LOAD MILLION BTU (Q502)	SOLAR FRACTION OF LOAD PERCENT (N500)	SOLAR ENERGY USED MILLION BTU (Q500)	OPER ENERGY MILLION BTU (Q503)	AUX THERMAL USED MILLION BTU (Q501)	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU (Q508)	ELECT ENERGY SAVINGS MILLION BTU (Q512)	FOSSIL ENERGY SAVINGS MILLION BTU (Q514)	BLDG DRY BULB TEMP DEG F (N406)	AMB TEMP DEG F (N113)
1	0.745	15	0.339	0.473	2.365	N	3.942	-0.030	0.565	74	56
2	1.666	18	0.571	1.008	6.091	O	10.151	-0.048	0.952	73	54
3	1.373	20	0.511	0.944	4.912	T	8.187	-0.045	0.852	73	54
4	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	71	59
5	0.000	0	0.000	0.000	0.000	A	0.000	0.000	0.000	69	63
6	1.583	37	1.048	1.191	6.024	P	10.040	-0.083	1.746	72	57
7	1.588	31	0.694	0.961	4.526	P	7.543	-0.066	1.157	73	56
8	1.392	31	0.724	0.939	4.651	L	7.751	-0.057	1.207	73	54
9	1.657	28	0.845	1.096	5.083	I	8.472	-0.070	1.409	74	55
10	1.647	34	0.853	1.170	5.744	C	9.573	-0.060	1.422	74	52
11	0.000	0	0.000	0.000	0.000	A	0.000	0.000	0.000	70	51
12	0.000	0	0.000	0.000	0.000	B	0.000	0.000	0.000	68	54
13	1.185	34	0.762	0.910	3.261	L	5.436	-0.121	1.270	71	60
14	0.000	0	0.000	0.000	0.000	E	0.000	0.000	0.000	72	61
15	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	73	58
16	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	73	62
17	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	71	59
18	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	69	53
19	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	67	52
20	1.170	5	0.316	0.816	4.215		7.025	-0.008	0.527	71	58
21	1.477	26	0.640	0.938	3.896		6.494	-0.059	1.066	75	60
22	1.562	52	1.276	1.123	3.717		6.195	-0.151	2.126	79	69
23	2.532	37	1.464	1.461	5.796		9.660	-0.133	2.441	80	68
24	2.258	28	0.971	1.223	8.105		13.508	-0.079	1.619	78	60
25	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	74	55
26	0.000	0	0.000	0.000	0.000		0.000	0.000	0.000	70	55
27	2.187	25	0.911	1.168	7.310		12.183	-0.077	1.518	73	61
28	3.753	19	1.330	2.100	11.814		19.691	-0.098	2.216	77	72
29	2.489	35	1.299	1.439	6.749		11.248	-0.185	2.165	82	79
30	2.220	42	1.447	1.837	7.770		12.950	-0.110	2.412	84	73
SUM	32.483	-	16.002	20.796	102.029	N.A.	170.048	-1.480	26.670	-	-
AVG	1.083	29	0.533	0.693	3.401	N.A.	5.668	-0.049	0.889	73	59
PFRV	0.9694	0.9694	0.9694	0.9694	0.9639	N.A.	0.9639	0.9694	0.9694	0.97	0.9694

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MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

THERMODYNAMIC CONVERSION EQUIPMENT

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	0.199	0.339	0.031	0.513	0.162
2	0.297	0.571	0.051	0.831	0.520
3	0.277	0.511	0.051	0.714	0.541
4	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000
6	0.580	1.048	0.084	1.488	0.554
7	0.489	0.694	0.070	1.139	0.704
8	0.436	0.724	0.060	1.194	0.603
9	0.469	0.845	0.072	1.218	0.555
10	0.560	0.853	0.061	1.473	0.656
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.438	0.762	0.125	0.665	0.512
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.057	0.316	0.012	0.098	0.179
21	0.380	0.640	0.063	0.970	0.594
22	0.813	1.276	0.152	2.244	0.637
23	0.939	1.464	0.134	2.493	0.641
24	0.627	0.971	0.079	1.692	0.645
25	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000
27	0.549	0.911	0.079	1.477	0.603
28	0.724	1.330	0.099	2.088	0.544
29	0.872	1.299	0.185	2.322	0.671
30	0.941	1.447	0.111	2.603	0.650
SUM	9.647	16.002	1.520	25.223	-
AVG	0.322	0.533	0.051	0.841	0.568
PFRV	0.9694	0.9694	0.9694	0.9694	0.9694

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MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

AUXILIARY THERMODYNAMIC CONVERSION EQUIPMENT

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	0.546	2.365	0.149	2.912	-0.203
2	1.369	6.091	0.345	7.560	0.241
3	1.097	4.912	0.317	6.009	0.226
4	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000
6	1.003	6.024	0.384	7.027	0.166
7	1.099	4.526	0.302	5.625	0.243
8	0.955	4.651	0.309	5.606	0.205
9	1.188	5.083	0.358	6.271	0.234
10	1.086	5.744	0.394	6.831	0.189
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.746	3.261	0.239	4.008	0.216
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	1.113	4.215	0.303	5.328	0.264
21	1.097	3.896	0.302	4.993	0.282
22	0.749	3.717	0.295	4.466	0.202
23	1.593	5.796	0.435	7.388	0.275
24	1.631	8.105	0.356	9.736	0.201
25	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000
27	1.638	7.310	0.337	8.948	0.224
28	3.029	11.814	0.686	14.843	0.256
29	1.616	6.749	0.351	8.365	0.239
30	1.278	7.770	0.589	9.048	0.165
SUM	22.836	102.029	6.453	124.965	-
AVG	0.761	3.401	0.215	4.166	0.236
PFRV	0.9694	0.9639	0.9694	0.9639	0.9639

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MONTHLY REPORT: SAN ANSELMO SCHOOL APRIL 1981

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)
1	1807	N	56	59	24	N	N
2	2042	O	54	63	21	O	O
3	2197	T	54	67	21	T	T
4	2177		59	73	23		
5	2159	A	63	79	25	A	A
6	2062	P	57	69	26	P	P
7	2095	P	56	69	26	P	P
8	2128	L	54	65	24	L	L
9	2114	I	55	68	25	I	I
10	2150	C	52	64	21	C	C
11	2167	A	51	62	21	A	A
12	2171	B	54	66	23	B	B
13	2164	L	60	76	22	L	L
14	2065	E	61	79	24	E	E
15	2013		58	70	26		
16	1844		62	78	27		
17	1506		59	70	30		
18	162		53	55	31		
19	502		52	57	31		
20	1773		58	67	29		
21	1985		60	72	29		
22	2071		69	83	29		
23	1966		68	86	31		
24	1957		60	72	29		
25	1026		55	63	27		
26	1739		55	63	26		
27	2071		61	73	26		
28	2068		72	87	25		
29	1973		79	95	29		
30	1900		73	90	30		
SUM	56054	N.A.	-	-	-	-	-
AVG	1868	N.A.	59	71	26	N.A.	N.A.
PFRV	0.9694	N.A.	0.9694	0.9694	0.9694	N.A.	N.A.

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*U.S. GOVERNMENT PRINTING OFFICE:1982-546-085/91