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SOLAR HEATING AND COOLING RESULTS FOR THE LOS ALAMOS STUDY CENTER

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ABSTRACT

Solar energy system performance data for one heating season and two cooling seasons are given for the Los Alamos National Security and Resources Study Center, a 60 000 ft^2 conference center and library at the Los Alamos Scientific Laboratory, New Mexico.

The solar energy system for the Study Center consists of an 8000 ft^2 array of selectively coated, single-glazed collectors, a 5000 gallon pressurized tank for hot storage in the cooling mode, and a 10 000 gallon tank, which is used for hot storage in the heating mode and cold storage in the cooling mode. Either of two chillers may be used in series with the cold storage tank, an 85 ton absorption unit, or a 77 ton Rankine cycle unit. Night evaporative cooling is also used to cool the 10 000 gallon tank. A heat recovery unit is used to preheat fresh air in the winter, and, by means of spraying the exhaust air, to pre-cool fresh air in the summer.

Daily, monthly, and seasonal energy summaries are presented for the system. Performance data for the two chillers include tabulation of thermal and system coefficients of performance.

Discussions of system operating experiences are included, particularly of the development of optimum solar cooling strategies, which increased the solar cooling fraction from 81% in 1977 to 97% in 1978. The solar heating fraction for the system was 79%.

SYSTEM DESCRIPTION

A schematic of the energy, heating, ventilating, and air conditioning system is shown in Fig. 1. The 7705 ft^2 collector array is architectually and structurally integrated into the building, forming the roof of the mechanical equipment room. The total air-conditioned floor area of the building is 60 000 ft^2 on three floors.

HVAC System

The HVAC system is a two-zone (perimeter and interior) variable air volume system with separate supply and return fans and cooling coils for each zone. Hot water coils for heating are provided in the perimeter zone only.

The air handling system features recirculation of inside air, and a heat pipe heat recovery unit in the perimeter zone system serves two functions: to preheat outside air in the heating mode; and, by means of spraying the exhaust air, to precool outside air in the cooling mode. The light fixtures are cooled by the return air. The main air supply units each have a cooling coil, an air washer, and a supply fan.

Energy System

The energy system consists of the solar collector array and heat exchanger, two storage tanks, and two water chillers - a lithium-bromide absorption chiller, and a Rankine cycle unit, either of which can be used for comparative studies of solar air-conditioning. The collectors are fabricated of mild steel, have a selective surface of black chrome, and are single-glazed with water-white glass. Four hundred and seven collectors are connected in parallel to form the array. The collectors are cooled with a light paraffinic oil heat transfer fluid.

In the heating mode, a 10 000 gallon tank is used to store hot water for heating. In the cooling mode, a 5000 gallon pressurized tank is used to store solar hot water to operate either of the chillers, and cold water is stored in the larger tank. Cold water is generated either by one of the chillers, which are in series with the larger tank, or by night evaporative cooling with a 500 gpm cooling tower, which is normally used to reject heat from the chillers.

The solar energy system is backed up by auxiliary steam heat exchangers that generate hot water directly for heating or to power the chillers. Domestic hot water is generated by means of a 100 gallon tank connected to the solar hot water tank, and augmented by an electrically heated 40 gallon tank downstream.

SYSTEM OPERATION

The heating and cooling system operates in two basic modes, which are subdivided as follows:

Winter Mode - Heating
- Mode 1 - Solar Heating
- Mode 2 - Auxiliary Heating

Summer Mode - Cooling
- Mode 3 - Solar Cooling
- Mode 4 - Auxiliary Cooling
- Mode 5 - Cooling from cold Storage
- Mode 6 - Night Evaporative Cold Storage

Heating Controls

The building control system demands hot water for heating at a temperature of 140°F if the ambient temperature is 0°F, and 70°F if the ambient is 70°F, with a linear profile as a function of ambient temperature. If the stored solar hot water drops below the required temperature, the auxiliary system is used for heating.

Cooling Controls

The cooling control system regulates the fan discharge temperature to satisfy the building cooling load. The building cooling sequence is activated in the following order:

1. Full Fresh Air
2. Air Washers Start
3. Exhaust Spray
4. Chilled Water from Cold Storage
5. Water Chiller Starts

In the originally installed system, once chiller operation was called for, stored solar hot water was used to provide energy to the chiller until the hot water tank temperature dropped below 170°F. Auxiliary hot water was then supplied at 190°F until the storage tank was heated to 180°F. At the end of the 1977 cooling system, modifications were made to the control system to improve the utilization of solar energy. In the present configuration, the chiller is started when the hot storage tank has been heated above 180°F, regardless of whether the building is calling for cooling. The chiller continues to operate until the hot tank drops below 170°F or until the cold tank drops below 48°F. Auxiliary operation is prohibited if the cold storage tank is below 65°F. This modified control scheme improves system performance by running the chiller when the collectors are operating, thereby reducing collector temperatures; forcing long chiller operating times at full capacity; prohibiting auxiliary operation until cold storage is exhausted.

Solar Collector Controls

A temperature probe on the back of the collector is used to compare collector temperature with the hot storage temperature. When a 10°F temperature differential is established, the collector pumps are started after a three minute delay.

SYSTEM THERMAL PERFORMANCE

About 160 channels of instrumentation are installed in the building for the purpose of evaluating the system performance. These measurements consist primarily of flow rates and temperature differences on all of the energy subsystems. In addition, electrical power consumptions of all of the pumps and fans are measured. Most temperatures are measured using platinum resistance thermometers. Flows are measured with turbine flowmeters and Annubar probes. Solar flux is measured in the plane of the collector and in the horizontal plane. Data acquisition is controlled by a PDP-11/34 computer, which automatically provides periodic energy summaries for display and storage.

Temperature probes were calibrated in the laboratory and as installed, and matched for temperature difference measurements. The resolution and accuracy of the resistance probes are .05°F and 0.2°F, respectively.

Monthly Energy Summary

The mean daily values of systems energies are given in Table 1. Generally, the data reported here are complete. Occasionally, one day or part of a day was lost for any given month. In these cases, estimates were made of the daily energy values to complete monthly records of daily summaries. The effect of the cooling control system modifications can be seen in the increase in percent solar from the 1977 to 1978 cooling season (85% to 97%). This is particularly evident in the August data (74% to 100%). The parasitic power term includes both solar pumps, hot water pumps, chilled water pump, cooling tower fan, condensor pump, and chiller internal power consumption.

Chiller Performance

Comparative chiller performance data are summarized in Table 2 for the 1978 cooling season. The comparison is between the absorption and the Rankine u . Thermal, solar, and system coefficients of performance are given. The thermal COP is the chiller cold water output energy divided by the chiller hot water input energy. The solar and system COPs are the chiller output divided by the system electrical energy input. The solar collector pump and heat exchanger pump, chiller hot water pump, and chiller internal powers are used in the solar COP calculations. The chilled water pump, the condensor pump and cooling tower fan powers are added to calculate the system COP.

Seasonal System Energy Summaries

The following four figures show the system solar performance and load characteristics on a seasonal basis.

Solar System Performance

Figure 2 gives the collector incident and output for the 1977-78 heating season. Figure 3 is the collector performance summary for the 1978 cooling season.

System Load

Figure 4 shows the portions of the building heating load provided by solar and auxiliary for the 1977-78 heating season. Figure 5 summarizes the chiller hot water consumption and chilled water output for the 1978 cooling season.

REFERENCES

1. H. S. Murray, J. C. Hedstrom, J. D. Balcomb, "Solar Heating and Cooling Performance of the Los Alamos National Security and Resources Study Center, CCMS/ISES Conference, Dusseldorf, April 19-23, 1978.

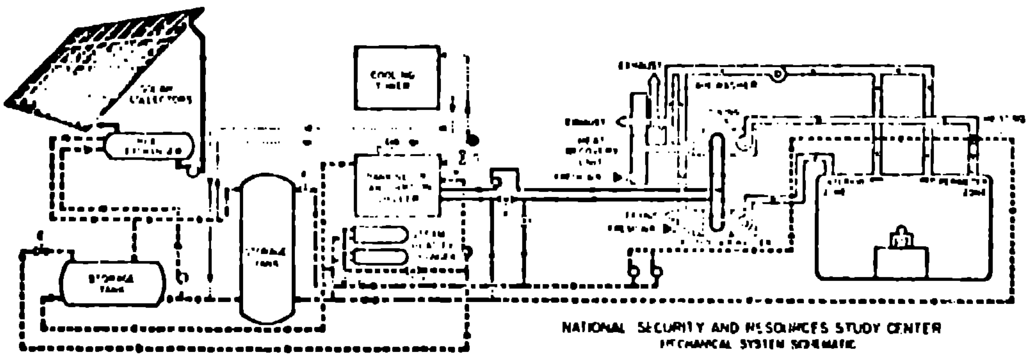

Fig. 1. NSRSC energy and HVAC system.

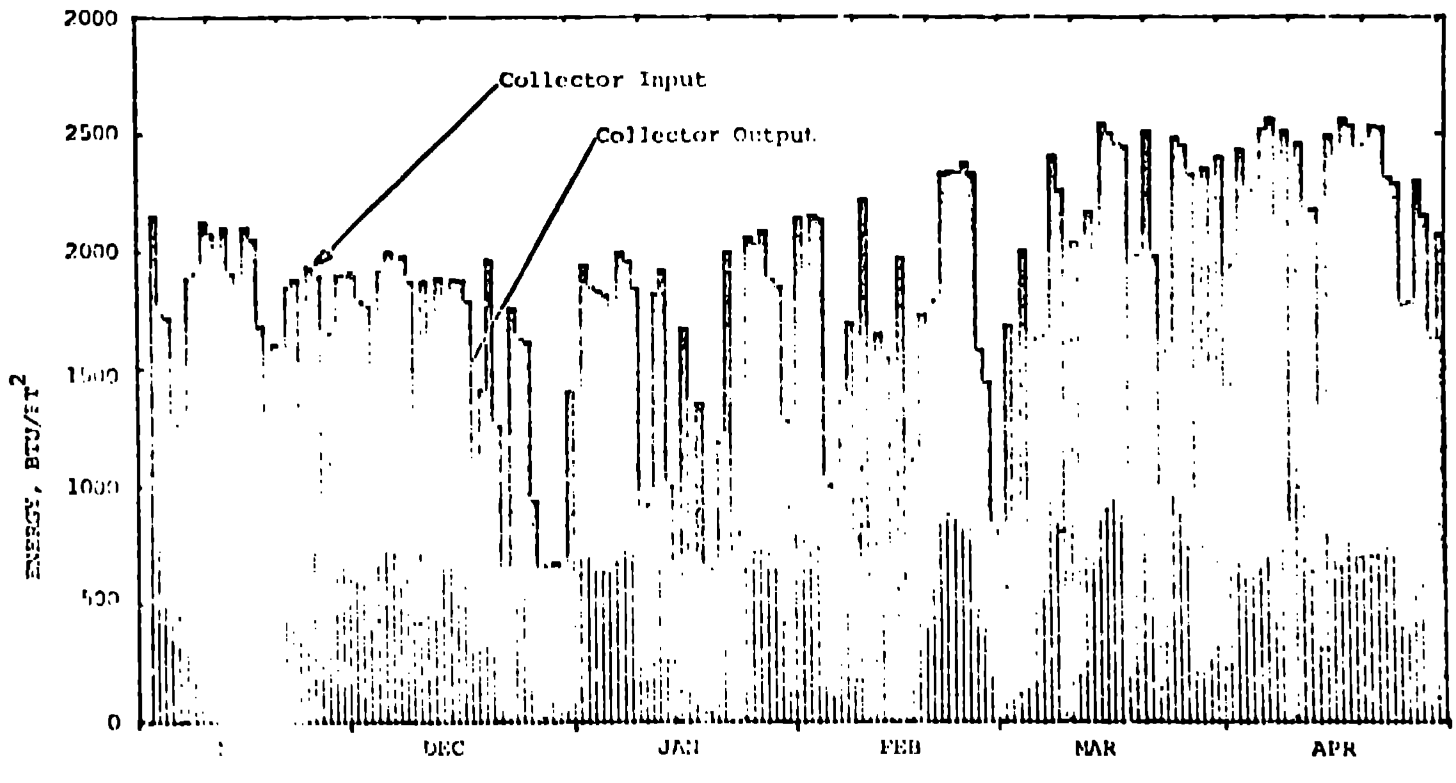

Fig. 2. Heating season collector input/output.

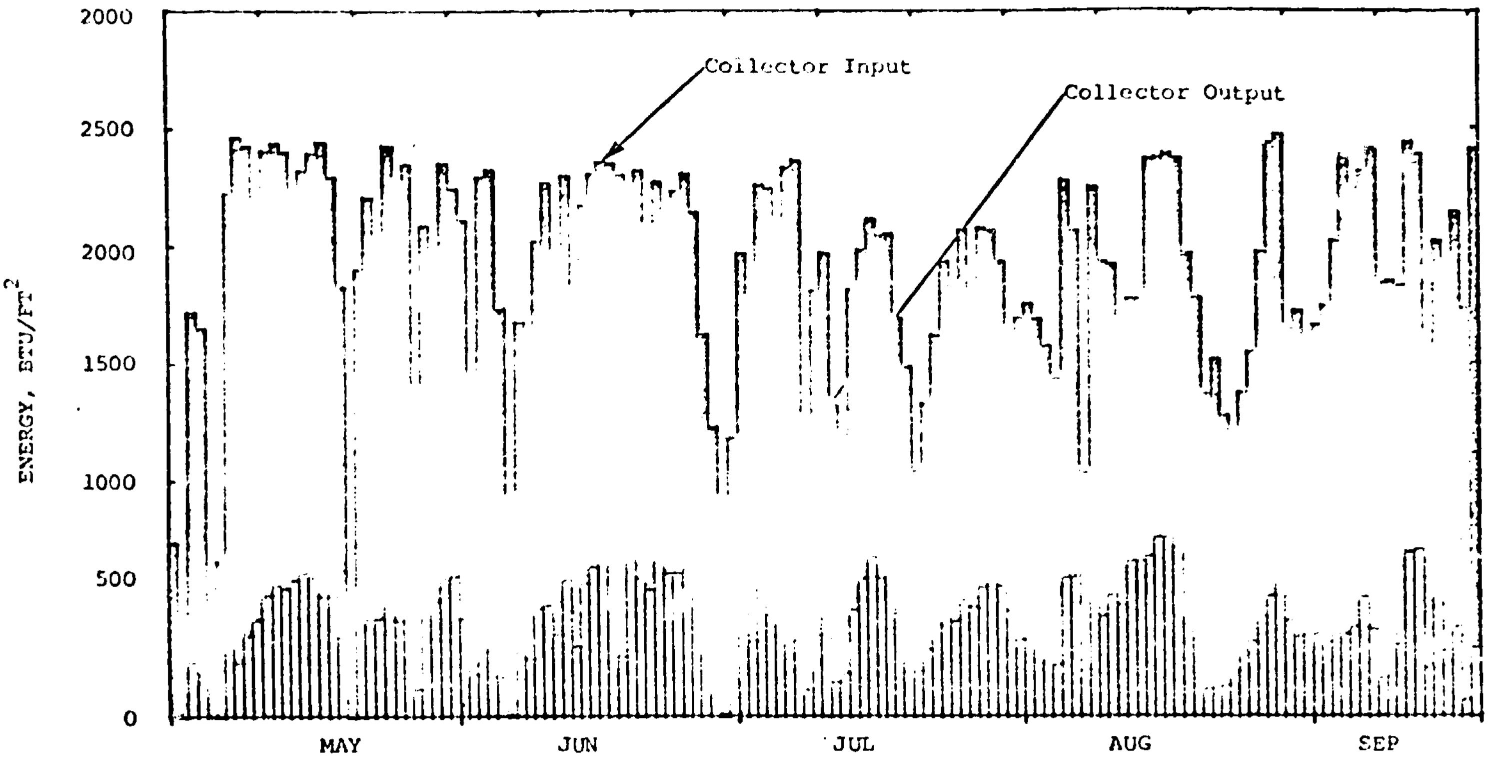

Fig. 3. Cooling season collector input/output.

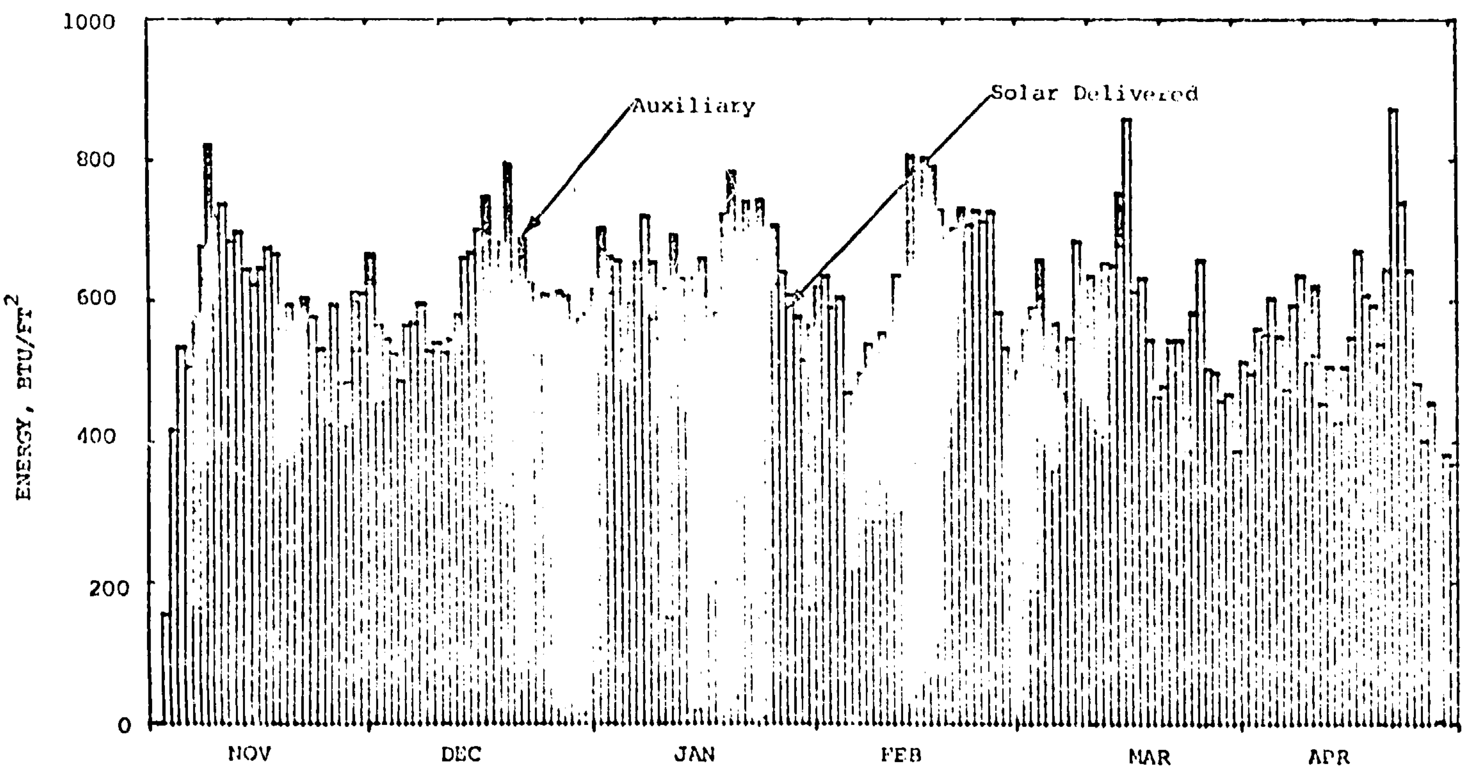

Fig. 4. Building heating load.

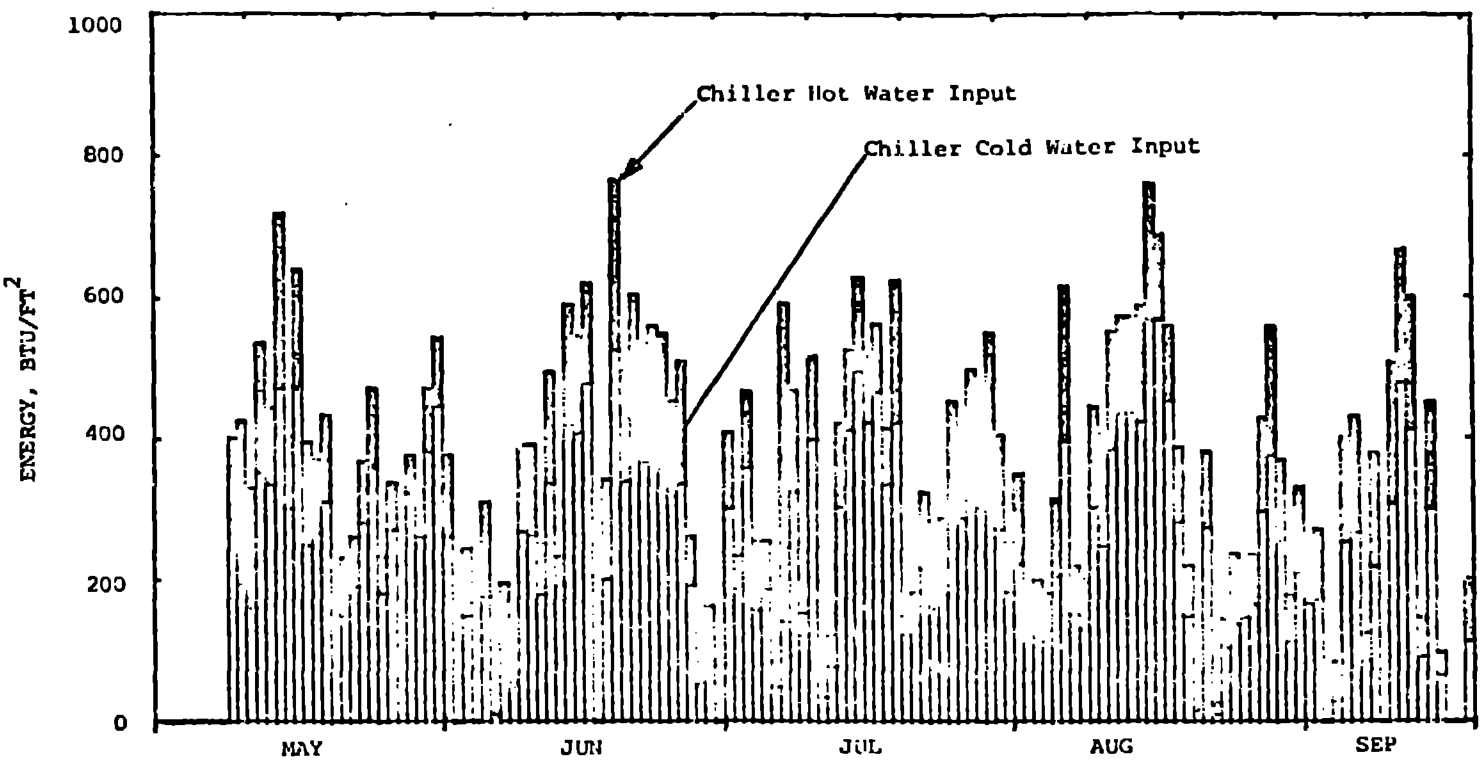

Fig. 5. Chiller performance.

TABLE 1

NATIONAL SECURITY AND RESOURCES STUDY CENTER, LOS ALAMOS, NM

ENERGY SUMMARY

MO	YR	COL IN	COL OUT	COL IN	STOR SH LD	STOR DHW	STOR CHL(1)	CHL OUT(1)	STOR LOSS	PRSTC POWER	SYS COP	COL EFF	AUX	% SOL
8	77	1650	437	378	0	12(2)	436	237	47	–	–	26	118	74
9	77	1729	408	351	0	12(2)	271	161	88	–	–	24	9	97
11	77	1607	563	647	482	11	0	0	154	33(2)	14.9	35	65	96
12	77	1499	501	527	434	11	0	0	82	36(2)	12.4	33	158	74
1	78	1403	465	480	387	13	0	0	80	34	11.8	33	238	63
2	78	1603	502	507	421	13	0	0	73	36	12.1	31	190	70
3	78	1800	595	593	473	13	0	0	107	37	13.1	33	77	86
4	78	2165	610	594	517	11	0	0	66	36	14.7	28	3	99
5	78	1913	368	346	0	15	282	201	49	55	3.69	19	0	100
6	78	1950	400	372	0	13	337	231	41	69	3.37	21	19	95
7	78	1828	416	391	0	11	373	258	40	71	3.63	23	33	92
8	78	1822	437	408	0	9	360	253	39	67	3.79	24	0	100
9	78	2050	365	334	0	6	256	164	72	57	2.88	18	0	100

Units: BTU/ft^2 day

(1) Total chiller energy including auxiliary.

(2) Estimated.

TABLE 2

NATIONAL SECURITY AND RESOURCES STUDY CENTER

CHILLER PERFORMANCE DATA

MON	CHILLER	CHILL HW	CHILL CW	THERM COP	POWER SOLAR	SOLAR COP	POWER TOT	SYS COP
5	ABS	403	244	.605	37	6.62	59	4.12
6	ABS	8994	6209	.690	1162	5.34	1787	3.06
7	ABS	2329	1408	.605	285	4.94	460	3.06
8	ABS	4827	3183	.660	560	5.68	939	3.39
T	ABS	16553	11044	.667	2044	5.4	3425	3.40
5	RANK	8370	6001	.717	909	6.60	1556	3.86
6	RANK	1131	738	.652	141	5.24	224	3.28
7	RANK	9247	6614	.715	1001	6.22	1753	3.77
8	RANK	6348	4668	.735	635	7.35	1133	4.12
T	RANK	25096	18021	.718	2686	6.71	4666	3.87

Energy Units: BTU/ft^2