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SUNCATCHER MONITORING PROJECT

QUARTERLY TECHNICAL REPORT 1
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EARTH INTEGRAL OF LIVING SYSTEMS
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TASK 3.0

Co-ordination with Los Alamos Scientific Laboratory Solar Group

On November 14 and 15, Bruce Maeda visited the Los Alamos Scientific Laboratory Solar Group's office to report on the progress of Department of Energy Grants numbers EG-77-G-04-4153 and EG-77-G-04-4154 and to submit modified time schedules for Task progress and completion. He discussed with Drs. Joseph Perry and Douglas Balcomb the work in progress on these tasks and other Living Systems' projects. Mr. Maeda obtained useful scientific papers which will aid in the overall scope of the D.O.E. grants EG-77-G-04-4153 and EG-77-G-04-4154. He also conferred with Bob Macfarland about programming and simulation techniques for remodeling solar thermal systems.

TASK 3.1

Equipment, purchase and Preparations

The following special equipment has been purchased and is in use:

- 1) Eppley double dome PSP pyranometer currently in use for radiation experiments and calibration of other radiation measuring devices.
- 2) IMSAI 8048 control computer kit.
- 3) Heathkit paper tape punch and reader.
- 4) Heathkit power supply, assembly in progress.
- 5) Weathermeasure anemometer and wind vane purchased. Interface electronics in progress.
- 6) Foylon for infrared experiments.

The following equipment has been ordered but has not arrived:

- 1) BTU meters from Hershey. Ordered December 1977

Electric watt-hour meters have been received on loan from P.G.&E. for

for the separate monitoring of the refrigerator/washer electric circuit and the lighting circuits. These are scheduled to be installed the second week of February. P.G.&E. has not yet installed their monitoring system of gas and electric use. This delay has not interfered or caused added delays in our schedule as of yet. However, our electronics will be ready shortly and further delay by P.G.&E. may cause additional project delays.

One additional piece of electronic equipment was purchased as a backup measure for the fully automatic monitoring system, a manual rotary switched amplifier for reading 1-10 thermocouple inputs. The thermocouple inputs must be referenced by a thermocouple at a known temperature to adjust the offset and gain of the device. This amplifier allows us to hand monitor locations which would be inconvenient if not impossible to monitor by thermometers. This device was designed by Ben Parks under direct commission from Living Systems at a cost of \$75.00.

TASK 3.1

Equipment Purchase and Preparations

Progress on the suncatcher monitoring project is running approximately six weeks behind schedule due to problems with a vendor who was to supply the data acquisition remote module. The company lost two key personnel and was unable to meet our needs for the project at the budgeted price. After considering the alternatives, we decided to design and build our own data acquisition system. This entailed additional work for our part which was not originally planned and thus has led to time delays and cost overruns for the equipment set-up costs.

The data acquisition system has three main components: the interfacing circuitry, the computer board, and the recording unit. The interface has the task of amplifying, multiplexing, and performing an analog to digital conversion on data present for up to 128 channels. Due to the large number

of channels, it was decided to multiplex before amplifying the signals. At first, reed switches were thought to be essential to insure accuracy, but later a CMOS analog multiplexer was found to be adequate. The amplifier is a high-performance modular CMOS chopper which will minimize problems with offset and noise. The analog to digital converter is a monolithic successive approximation type which provides 8-bit resolution. The interface board is being designed and will be constructed soon.

The computer controls the multiplexing, amplification, and conversion, and receives the 8-bit data words from the ADC through its I/O port. Then the data is stored temporarily in RAM and later transferred to the recording unit, also under computer control. The computer board (IMSAI Manufacturing Corporation) is based on the Intel 8048 one-chip micro-computer. This system is well suited for the relatively simple tasks required of it by the application. Pre-processing of data will be kept to a minimum since all programming is done in machine language. Since the interrupt capabilities of 8048 have been pre-empted by the PROM monitor supplied by the manufacturer, the on-board timer will not be used for elapsed time in the data logging. Real time will be provided by an external crystal controlled clock which will be interrogated by the computer. The computer board is constructed and fully operational.

The data recording medium is paper tape rather than cassette tape as originally planned. This type of system is considered to be more reliable than most low-cost audio cassette systems. The data will be transferred to the main computer on the U.C. Davis campus. The paper tape will provide a non-volatile data archiving system along with a magnetic tape-based working data file for data reduction, analysis, and summary. The paper tape reader/punch (HeathKit from Heath Company) has been constructed and is fully operational.

TASK 3.2

Sensor Installation

Most of Task 3.2 was completed before the grant was obtained. However, additional thermocouple wire was laid under the parquet flooring in late September and October 1977 for the slab transect of temperature sensors. Some modifications were made in the thermocouple layout to accommodate suggestions made during contract negotiations by Dr. Joseph Perry, Jr. In November 1977 thermocouples were installed in the neighboring flat plate collector and its inlet and outlet pipes. In January 1978 corrections were made in the thermocouple installation in the breadbox hot water heater due to potential problems with displacement during hot sunny periods and air heating of the thermocouple junctions.

After consideration of some of the aspects of the Suncatcher ceiling line and noticing stratification effects in the house itself, a decision was made to include additional thermocouples at different heights in the hallway. The placement will be at five, ten, and fourteen foot heights in two hallway locations. One of these stations will be directly under the recirculating fan and the other will be in a location of more stagnant air. Approval had to be obtained from the residents since these thermocouple wires will be more exposed than the ones placed during construction of the residence.

TASK 3.3

House Comfort Monitoring

In anticipation that delays might be encountered in the data acquisition system set-up, a manual monitoring procedure was established for the gathering of temperature and utility data. Measurements were started on November 2, 1977, but the full procedure was not implemented before November 25, 1977. Once the automated data acquisition system is set up and fully operational some hand monitoring will continue to be taken on a regular basis but the scope of the measurements will be reduced. These hand measurements will be used for comparative purposes in the analyses.

We are now receiving the weather summaries from the Davis Benchmark weather station and some of this data is used in conjunction with the graphs of temperature performance of the Suncatcher house. In particular, radiation and outside maximum and minimum temperatures are plotted from the Davis weather station.

Maxmin thermometers are located in three locations:

- 1) North dining room area near the North facing french doors.
- 2) Outside the french doors, hanging on the door knob.
- 3) Between the middle of the fourth and fifth tubes on the floor.

In addition to the maximum and minimum temperatures, current temperatures are read daily at 8:00 in the morning Pacific Standard Time. Electronic temperature sensors are placed at three different heights on the middle tube in the Suncatcher hallway. They are on the shaded side and are insulated from the ambient interior air temperature. The sensors and insulation are taped to the exterior surface of the metal water storage cylinders at heights of 0.1 foot, five feet, and ten feet. The utility meters are read concurrently with the temperature readings at 8:00 a.m. daily. Preliminary plots of temperature, radiation, and gas usage data are given in figures five to fourteen.

TASK 3.4

Experiments and Intensive Monitoring Periods

In the revised time line submitted to Dr. Joseph Perry, we proposed trial experiments in December of 1977 and January, 1978 to evaluate the kinds of problems that might occur during the actual experiments. These experiments will be repeated in December, 1978 and January, 1979. As per negotiations in September of 1977, the radiation mapping experiments will be repeated in April, 1978, June, 1978 and August or September, 1978 in addition to the December 1978 session. Scheduling and the inclement weather permitted only two trial

radiation mapping sessions and both of these were not able to incorporate a full day's data gathering. The first radiation mapping was attempted on December 30, 1977. This data was taken before the insulative, reflective shutters were installed on the high south facing Suncatcher windows. The day was partly cloudy, making accurate clear sky measurements extremely difficult. The patchiness of the cloud cover made comparative data less valuable than desired. In addition only Bruce Maeda was available to gather the data, making data gathering more difficult and time consuming.

On January 10, 1978 a more complete set of radiation data was obtained. Early morning measurements were complicated by equipment problems, but these were resolved by 11:30 a.m. Pacific Standard Time and very complete data were gathered every half hour until 4:30 p.m. when the sun set behind low clouds. These measurements were taken in thirteen different locations, twelve of which are shown in figure one. The location not shown was at the five foot level of the South room window with the pyranometer facing perpendicular to the glazing in a vertical position. This was the reference position to determine the "normal" amount of solar radiation transmitted through South facing vertical double glazing to compare to the Suncatcher windows. The raw data is given at the end of the Suncatcher radiation plots. Data was not taken at 4:30 p.m. due to the onset of darkness. The Suncatcher Solar Radiation data are plotted and given in figures two to four following the text of this report. The errors in these data are estimated at ten percent except for the lower readings which had a low bit resolution of one tenth of a millivolt. This corresponds to 3 BTUH/sq.ft. In later reports this data will be least squares fit to parabolic curves.

TASKS 3.5 - 3.7

Water Heater Tests

Infrared Radiation Tests

Wind Speed Monitoring

Work on these tasks has not yet begun.

TASK 3.8

Natural Gas and Electric Use

Gas and electric use are currently being hand monitored and recorded on a daily basis as indicated in Task 3.3. Gas usage is plotted in figures nine and fourteen for comparison with temperature and radiation data overlays. The plots give data for November and December of 1977 on separate sets of transparencies. Pacific Gas and Electric Company has yet to install the digital monitoring devices and the extra gas meters as they had agreed to do before the grant notification. Hand monitoring will continue until we are actually receiving data from Pacific Gas and Electric Company, so that we may avoid potential data gaps.

RADIATION MEASUREMENT POSITIONS
FIGURE ONE

T

+
FIGURE TWO

T

FIGURE THREE

T

FIGURE FOUR

T

+

-

NOV 1977 OUTSIDE

FIGURE FIVE

T

+

-

NOV 1971 N. DINING

FIGURE SIX

T

+

-

NOV 1971 STUDY 8:00AM

FIGURE SEVEN

T

+

-

NOV 1971 RADIATION

FIGURE EIGHT

T

NOV 1977 GAG

FIGURE NINE

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+

-

FIGURE TEN

DEC 1977 OUTSIDE

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+

-

FIGURE ELEVEN

DEC 1971 N. DINING

T

+

-

FIGURE TWELVE

DEC 1977 STUDY 8:00 AM

T

+

-

FIGURE THIRTEEN

DEC 1971 RADIATION

T

FIGURE FOURTEEN

DEC 1977 OAS

SUN CATCHER RADIATION GRAPHS

MAXIMUM & MINIMUM DAILY TEMPERATURES
RADIATION AND GAS USAGE

NOVEMBER 1977 TEMPERATURES
(Degrees Farenheit)

R - Rain
F - Fog
D - Drizzle
M - Missing

Date	Outside		North Dining (Coldest Part of House)		Study	Gas Use		Radiation	
	Max.	Min.	Max.	Min.		ft. ³		Langleys/day	
1	68	46						R	362
2	73	45							337
3	75	47			69	10			353
4	64	44			72	70		R	235
5	67	49			73	40		R	310
6	61	47	73	64	72	80			351
7	66	52	69	64	70	20			272
8	71	54	74	61	68	75			298
9	70	41	73	64	68	55			308
10	67	46	84	65	69	40			215
11	67	47	71	65	69	120			211
12	67	46	70	65	70	80			287
13	68	46	72	65	70	50		M	
14	68	47	71	64	70	100			234
15	70	46	70	65	70	60			288
16	73	49	73	66	71	60			327
17	75	49	74	67	71	40			233
18	68	45	72	65	70	50			280
19	66	34	72	63	68	50			260
20	53	31	74	60	66	50		R	239
21	51	40	66	60	66	170		R	32
22	54	44	67	63	68	680		R	249
23	61	43	72	64	M	100			197
24	54	47	72	64	M	260			284
25	62	46	75	64	68.5	20			277
26	66	47	74	65	70	20		F	280
27	68	48	75	66	71	60		F	189
28	62	49	71	64	70	60			257
29	70	42	72	66	70	80		F	195
30	63	53	72	67	70	30			270
						2430			261

DECEMBER 1977 TEMPERATURES
(Degrees Farenheit)

R - Rain
F - Fog
D - Drizzle
M - Missing

NATIONAL
42-383
NOV 1976

Date	Outside		North Dining (Coldest Part of House)		Study	Gas Use ft. ³	Radiation Langleys/day	
	Max.	Min.	Max.	Min.				
1	70	46	72	66	71	70	7	F 215
2	63	42	73	65	69.5	30	12.5	F 224
3	62	41	74	64	69	70	13.5	F 137
4	60	40	72	64	68	100	15	D/F 118
5	61	42	70	64	68	200	13.5	D/F M
6	60	48	73	64	68	70	11	D/F 102
7	56	48	73	64	68	70	13	D/F 84
8	54	41	69	64	67.5	250	17.5	246
9	56	35	76	62	M	50	19.5	D/F 131
10	50	32	69	62	68	450	24	D/F 136
11	49	42	72	64	67	100	19.5	D/F 94
12	54	47	68	63	67	310		R 135
13	56	46	69	63	66	100		R 168
14	56	46	67	62	65	250		R 40
15	62	55	71	62	68	300		R 204
16	61	44	72	62	66	60		R 84
17	53	49	67	62	64	300		R 87
18	57	40	71	62	65	340		R 201
19	53	37	70	59	M	150		234
20	50	38	69	58	66	(680)		136
21	49	47	70	58	66			R 60
22	56	50	70	62	64	140		R 70
23	59	52	72	62	66	400		R 215
24	62	47	72	66	68	150		192
25	57	47	75	61	M	40		126
26	54	48	66	61	64	180		R 58
27	52	47	68	62	M	290		R 77
28	52	51	M	M	M	(490)		R 60
29	54	52	71	62	65			R 119
30	59	48	69	63	64.5	140		200
31	59	43	75	61	64.5	160		263
						6130		140.

RADIATION MAPPING
January 10, 1978
(Readings in Millivolts)

	TUBES									South-facing		
	10 ft. Level			5 ft. Level			Horizontal			Clerestory Window		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
0:00 a.m.	0.3	4.7	4.9	0.2	0.6	0.8	0.2	0.3	0.4	7.6	8.1	7.6
0:30												
1:00												
1:30	0.7	6.2	5.5	0.2	0.3	0.4	0.4	0.8	0.9	9.8	10.4	11.8
2:00 p.m.	6.3	6.5	5.9	0.4	0.6	1.1	0.8	0.8	0.7	11.1	12.5	10.5
2:30	5.9	6.3	5.9	0.4	0.5	1.2	1.3	1.1	1.0	11.6	11.1	10.7
3:00	6.4	6.3	6.0	0.4	0.5	1.0	1.3	1.0	0.9	10.5	10.0	10.0
3:30	6.2	5.8	6.0	0.6	0.7	1.2	0.6	0.6	0.3	9.0	9.6	8.7
4:00	6.5	5.7	5.0	0.7	0.9	0.2	0.5	0.4	0.2	8.0	7.2	8.0
4:30	5.5	5.0	3.9	1.1	0.7	0.1	0.4	0.3	0.1	6.8	6.6	6.3
5:00	4.6	4.2	0.2	0.1	0.5	1.1	0.3	0.2	0.1	5.4	5.2	3.1
5:30	4.2	2.9	0.2	0.1	0.2	1.1	0.3	0.2	0.1	4.1	4.1	0.4
6:00	2.8	0.3	0.1	0.1	0.1	0.5	0.2	0.1	0.0	2.6	3.0	0.3
6:30				Sun almost down/clouds								

	South Windows			Tube Temperatures		
				Bottom	Middle	Top
0:00 a.m.				69°	70°	73°
0:00		5.4				
1:30		6.8				
2:00 p.m.		7.0				
2:30		6.7		70°	72°	79°
3:00		6.6		70°	73°	80°
3:30		6.0		70°	73°	81°
4:00		5.8		70°	73°	82°
4:30		5.3		70°	74°	82°
5:00		4.3		70°	74°	83.5°
5:30		3.8		70°	74°	84°
6:00	(clouds)	0.5		70°	74°	84°

(Degrees Farenheit)