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SUNCATCHER MONITORING PROJECT

QUARTERLY TECHNICAL REPORTS 2 & 3
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EARTH INTEGRAL OF LIVING SYSTEMS
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SUNCATCHER MONITORING PROJECT
QUARTERLY TECHNICAL REPORTS 2 & 3

This report is a combination of Quarterly Technical Reports two and three for the Department of Energy (E.R.D.A.) Grant Number EG-77-G-04-4154. The first section is a task-by-task outline of work progress scheduling. The second section consists of graphical and explanatory texts of the work done during the two quarters from January 1978 through June 1978.

A supplement to this report will be completed during August 1978 and will extend the performance estimates through June 1978 and graphically and analytically present the data for the June radiation mapping done on June 25, 1978.

TASK-BY-TASK REPORT

Task 3.0 CO-ORDINATION WITH ERDA'S NATIONAL PASSIVE EFFORT

This task was completed in November 1977 and reported in the first technical progress report.

Task 3.1 EQUIPMENT PURCHASE AND PREPARATIONS

All equipment has been purchased except for one BTU meter for monitoring the flat plate collector for the side-by-side test. The data acquisition system is fully constructed and operational. The system includes IMSAI 8048 controller based, real time clock, multiplexing and amplifying unit and power supply. The programming and calibration are complete for data gathering. Minor problems exist with the paper tape punch used for recording data so that it is very difficult to accurately set the hole punching calibration to 50 holes per inch. The accuracy we now have may be sufficient or we may be able to bypass this problem. Data reading and analysis software is in progress.

Task 3.2 SENSOR INSTALLATION

Virtually all sensor are now in place. The remaining sensors will be installed by August 1, 1978. They include outside ground temperature sensors for the slab transect, the mean radiant temperature and wet bulb sensors for the comfort stations, and

radiation shielding for the outside temperature sensor. The second BTU meter for the breadbox - flat plate comparison is not yet purchased pr omsta;;ed/

Task 3.3 HOUSE COMFORT MONITORING

Hand monitoring of max/min temperature in three locations, and 8:00 am tube temperature. The procedure was modified March 1, 1978 with position changes for two max/min thermometers. Outside temperature readings were being affected by early morning and late afternoon summer sun, so a cheesecloth shading cover was fitted to the thermometer. In spite of this, readings appear to be in substantial disagreement with Davis weather records, thus a better shield and/or placement change will occur August 1, 1978. Greater care of sun shielding will be taken on the outside thermocouple sensor.

Hand monitoring will continue as a check on the data acquisition system and as a comparative low cost performance measuring procedure. The effort will be scaled down slightly August 1, 1978, after the data acquisition system check-out period is complete.

Within the next month a 24 - 40 hour synoptic of hand read measurements will be done to compare computer gathered data as part of the data acquisition system check-out procedure.

In the first quarterly report we promised to do least square fits to the solar mapping data. This was done for both the January 10, 1977 and

May 9, 1978 data. Parabolic fits proved to be poor. This is attributed to the geometry of the suncatcher and the structure enhancing and limiting radiation in a complex fashion. The data will allow good tests of the geometric modeling of suncatcher radiation enhancement.

Comparison simplified technique calculations have been run and are being compared to performance estimates of the suncatcher. The more complete hour-by-hour modeling comparisons are yet to be done. Currently programming and algorithm checkouts are in progress.

Graphic displays of the performance of the suncatcher house are given in figures six through nine. Performance estimates are based on theoretical building loads calculated from shell heat loss and infiltration factors. South windows and suncatcher clerestory window heat losses are included in the building loads. The building heat loss calculations assumed shuttered and draped windows. Shutters in the clerestory were not installed until December 31, 1978 and roman shades on the North windows were not installed until July 1, 1978. Hence, the actual building load and performance was less than if the full conservation/solar system was fully in place. A roller drape for a small two feet by three feet North kitchen window and a large South study window remain to be installed. Again these installations will improve the performance slightly. The shutter latching system needs to be modified and this remains to be done. However, summer effectiveness of the shutters relies more on their reflectivity than on their sealability.

Task 3.4 EXPERIMENTS AND INTENSIVE MONITORING PERIODS

3.4A Basal Energy Use

Scheduled for December, 1978.

3.4B Radiation Monitoring of Tubes

Will begin August 1, 1978.

3.4C Radiation Distribution Experiment

Radiation mappings were done on May 9, 1978 and June 25, 1978. The data for May 9, 1978 is presented in figures two through five.

Least squares quadratic fits were done for both the May 9 data and the January 10, 1978 data. The results were similar. A polynomial quadratic fit to the data appears inappropriate, due in part to the effects of the suncatcher reflection system. Hence only two of these graphs are presented as illustration details. The radiation peaking is sharper than a parabolic fit of the full data. Graphs of several sample stations are given in figure two. Stations are shown in a copy of the interior rendering submitted in the last report.

3.4D Outside Radiation Comparison

Scheduled Winter 1978 - 1979.

3.4E Storage Temperature Monitoring

Complete data acquisition system monitoring start-up August 1, 1978.

Task 3.5 SOLAR HOT WATER HEATER TESTS

3.5A Breadbox Monitoring

Low minimum water temperatures from the breadbox ranged from 99 to 110 degrees fahrenheit from June 7 through June 20. Maximum breadbox temperatures ranged from 120 to 140 degrees fahrenheit.

Task 3.6 INFRA-RED RADIATION TESTS

3.6A Experiment on Radiant Isolation of Storage

Scheduled Winter 1978. Summer trial run will be done in a significant hot weather event in August or September 1978.

3.6B Radiant Isolation of Windows

Scheduled Winter 1978. There will be a summer trial run in August or September 1978.

Task 3.7 WIND SPEED MONITORING

An anemometer was installed in May 1978, and interfaced to the computer July, 1978.

• Task 3.8 GAS AND ELECTRIC USE

3.8A Gas Use

Additional gas meters were installed February 2, 1978. Separate metering is provided for hot water heater and furnace. Range is tabulated as a residual.

3.8B Electricity Use

Electric meters to monitor separate refrigerator and light usage were installed March 5, 1978. Other electric usage is determined as a residual.

RADIATION MEASUREMENT POSITIONS
FIGURE ONE

solar radiation mapping suncatcher

insolation 5-9-'78

▲ study ■ middle clerestory
 ● 10' middle tube ○ 5' middle tube

FIGURE TWO

* stations refer to figure one

reference point	9' Level	5' Level	.5' Level	outside	study	Living
maximum temp. °F	80.5	77.5	73.5	83.0	78.8	78.0
eLapsed time From 8:00 a.m.	9.0	10.0	9.0	7.0	7.5	9.0

FIGURE THREE

fit: $r = -0.07(t-4.5)^2 + 2.02$

where:

r = readings in W/m^2
 t = time elapsed

x_i	y_i	y_i LSP
0	60.1	59.1
.5	60.1	89.6
1.0	70.5	115.8
1.5	0.8	139.0
2.0	141.0	159.1
2.5	181.3	174.2
3.0	191.3	187.3
3.5	251.8	96.4
4.0	251.8	201.4
4.5	231.6	203.4
5.0	23.6	201.4
5.5	211.5	196.4
6.0	191.3	187.3
6.5	161.1	174.2
7.0	120.8	159.1
7.5	100.7	139.0
8.0	80.6	115.8
8.5	60.1	89.6
9.0	30.2	25.2
10.5	20.1	-53.1

FIGURE FOUR

Fit: $r = -0.05(t-4.0)^2 + 1.61$

where:

r = readings in w/m^2
 t = elapsed time

x_i	y_i	y_i LSP
0.0	60.4	89.6
0.5	70.5	106.7
1.0	90.6	120.8
1.5	30.9	33.9
2.0	141.0	141.0
2.5	181.3	152.1
3.0	181.3	158.1
3.5	211.5	161.1
4.0	211.5	162.1
4.5	191.3	161.1
5.0	130.9	158.1
5.5	51.1	152.1
6.0	130.9	141.0
6.5	120.8	133.9
7.0	100.7	120.8
7.5	80.6	106.7
8.0	60.4	89.6
8.5	50.1	69.5
9.5	0.3	21.2
10.5	20.1	-30.2

FIGURE FIVE

suncatcher daily performance

- inside daily maximum, °F
- inside daily minimum
- outside daily maximum
- outside daily minimum

vertical scale: (100) 10"

radiation,
Langley's

temperature,
degrees
Fahrenheit

FIGURE SIX

)

The preceeding figure displays daily maximum and minimum temperatures for inside and outside the 1368 square foot suncatcher house located in Davis, California for November 1977 to March 31, 1978. In addition, this graph displays the solar radiation on a horizontal surface as taken from the University of California at Davis solar radiation station. Anomalous high temperature was recorded early in November 1977 due to a max/min thermometer accidentally being exposed to direct sunlight. The data station shift on March 1, 1978 prevented the recurrence of this problem. Low inside temperatures and poor performance were coincident with days when low temperature and low radiation occurred together. For consequential reports and a supplement to this report a gas usage graph with the same data scale will be given just below this graph for a more complete day-to-day performance picture.

monthly temperature
averages , °F.

data table

	nov.	dec.	jan.	feb.	mar.	apr.
inside avg. max.	72.3	70.8	70.0	70.6	73.7	73.2
inside avg. min.	64.2	62.5	63.1	64.5	67.7	66.8
inside avg.	68.3	66.7	66.6	67.6	70.7	70.0
outside avg. max.	66.1	56.7	56.6	57.6	66.5	66.6
outside avg. min.	41.5	43.9	44.9	41.9	46.9	44.6

FIGURE SEVEN

insolation data table

	nov.	dec.	jan.	feb.	mar.	apr.	$\bar{x}$
kbtu/ft ² -month	29.3	16.1	17.1	18.1	26.3	33.8	23.5
23 year avg.	21	18	20	25	14	58	31.5
% of normal	122	89	87	72	59	58	75

FIGURE EIGHT

FIGURE NINE

- based on theoretical Load

heating degree days

	nov.	dec.	jan.	Feb.	mar.	apr.	$\bar{x}$
this year	331.5	465.5	445.5	426.5	256.0	282.5	384.6
29 year avg.	354.0	589.0	620.0	431.0	378.0	230.0	433.7

heating Load in millions of btu's

	nov.	dec.	jan.	Feb.	mar.	apr.
estimated Load	9.1	12.7	12.2	11.7	7.0	7.7
net solar	6.2	6.3	5.7	6.7	4.3	6.2

5/9/78
SOLAR
RADIATION
MAPPING

	STUDY S. CLASS	WEST END CLERESTORY	MIDDLE CLERESTORY	EAST CLERESTORY	10' W. END TUBE	10' MIDDLE TUBE	10' E. END TUBE	5' W. END TUBE	5' MIDDLE TUBE	5' E. END TUBE	WEST END HALL FLOOR	MIDDLE HALL FLOOR	EAST END HALL FLOOR	9' TUBE TEMPERATURE	5' TUBE TEMPERATURE	3' TUBE TEMPERATURE	LIVING ROOM TEMPERATURE	STUDY TEMPERATURE	OUTSIDE TEMPERATURE
														° F.	° F.	° F.	° F.	° F.	° F.
8:00														74°	72°	70°	67.4	66.5	61.5
8:30	0.4	0.6	0.6	0.6	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	74	73	71	68	66.7	66
9:00	0.6	0.7	0.7	0.6	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	75	74	72	70.7	70.5	70.2
9:30	0.7	0.9	0.9	0.7	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	75	74	72	71	70.5	70.3
10:00	0.8	1.2	1.3	1.1	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.1	76	75	72	72.2	72.2	73.8
10:30	1.4	1.3	1.4	1.4	0.5	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	76	74.5	72	73.0	73.0	76.1
11:00	1.9	1.6	1.8	1.8	0.5	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.1	76	75	72	73.8	74.4	76.7
11:30	2.1	1.5	1.8	1.9	0.5	0.5	0.4	0.2	0.2	0.1	0.1	0.2	0.1	76.5	75.5	72	74.5	75.4	78.5
12:15	2.5	1.6	2.1	2.5	0.6	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	77	75	72	75.0	76.5	78.5
12:30	2.7	2.7	2.1	2.5	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	77	75	72	75.5	77	77.5
13:00	2.7	1.4	1.9	2.3	0.5	0.4	0.5	0.2	0.2	0.2	0.2	0.2	0.2	78	76	73	76	78	82.5
13:30	2.6	1.7	1.3	2.3	0.4	0.4	0.4	0.1	0.2	0.2	0.1	0.1	0.1	78	76	73	76.5	78.1	82.5
14:00	2.5	1.2	1.5	2.1	0.4	0.4	0.4	0.1	0.2	0.2	0.1	0.1	0.1	78	76	73	76.6	78.4	81.7
14:30	2.5	1.0	1.3	1.9	0.4	0.3	0.4	0.1	0.2	0.1	0.1	0.1	0.1	79	76	73	77.1	78.5	81.3
15:00	1.9	0.8	1.2	1.6	0.3	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.1	79	76	73	77	78.6	83.0
15:30	1.2	0.7	1.0	1.2	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	79.5	76.5	73	77.5	78.8	82.0
16:00	0.7	0.6	0.8	1.0	0.2	0.2	0.3	0.1	0.1	0.1	0.0	0.1	0.1	78.5	76	73	77	78.5	82.7
16:30	0.5	0.4	0.6	0.8	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.1	0.1	79.5	76	73	77.5	77.5	82.2
17:00	0.5	0.4	0.5	0.6	0.2	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0	80.5	77	73.5	78	78.7	82.0
18:00	0.4	0.3	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	80.0	77.5	73.5	77.4	77.7	81.0 (sun)
19:00	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	79	76	73.5	75.5	76.7	
20:00														77.5	76	73	74.3	71.7	66.8
21:00														78.0	76	72.5	72.5	69.0	62.3
22:00														76.5	75.0	72	71.3	67.5	59.5
23:00														75.5	74	72	69.5	64.5	58
24:00														76	74	72	67.7	63	

NOTE: Readings in millivolts.

Instrument calibration
10.07 microvolts per watt per
meter squared.

TABLE ONE

SUNCATCHER HOUSE NOVEMBER, 1977 THROUGH APRIL, 1978

MONTH	ACTUAL USAGE (10 ⁶ BTU's)					10 ⁶ BTU's OTHER INTERNAL GAIN (PEOPLE)	% SOLAR	% OTHER INTERNAL GAIN
	TOTAL GAS	DOMESTIC HOT WATER	TOTAL GAS - D.H.W.	TOTAL ELECTRICITY	TOTAL HEATING			
November	2.480	(.564)	1.916	.6512	2.567	.270	68.68	2.98
December	5.993	(.564)	5.429	.7611	6.190	.279	49.14	2.19
January	6.053	(.564)	5.489	.7304	6.219	.279	46.62	2.29
February	4.568	.452	4.116	.5700	4.686	.252	57.62	2.16
March	2.210	.405	1.805	.5836	2.389	.279	61.86	3.99
April	1.550	.835	.715	.5666	1.282	.270	79.91	3.50

MONTH	THEORETICAL LOAD - CONVEC- TION 10 ⁶ BTU		THEORETICAL LOAD - INFIL- TRATION 10 ⁶ BTU		TOTAL THEOR. LOAD 10 ⁶ BTU	ESTIMATED LOAD 10 ⁶ BTU	OTHER GAINS AND TOTAL HEAT 10 ⁶ BTU	NET SOLAR 10 ⁶ BTU
November	3.829		1.606		5.435	9.058	2.837	6.221
December	5.377		2.255		7.632	12.720	6.469	6.251
January	5.146		2.158		7.304	12.173	6.498	5.675
February	4.926		2.066		6.992	11.653	4.938	6.715
March	2.957		1.240		4.197	6.995	2.668	4.327
April	3.266		1.369		4.635	7.725	1.552	6.173

INSOLATION BTU's/HR. · FT.²

MONTH	MEASURED			HORIZONTAL		SOUTH FACING VERTICAL			TOTAL
	H	H	K	DIFFUSE	DIRECT	REFLECTED	DIFFUSE	DIRECT	
November,	976	1668	.59	287.9	688.1	97.6	144.0	1321	1563
December	518	1308	.40	222.7	295.3	51.8	111.4	670	833
January,	561	1440	.39	258.1	302.9	56.1	129.1	666	851
February	645	1929	.33	348.3	296.7	64.5	174.2	415	654
March	349	2545	.33	458.5	390.5	84.9	229.3	344	658
April	1127.8	3175	.36	563.9	563.9	112.8	282.0	248	643

TABLE TWO