DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150593

MODULAR CONTROL SUBSYSTEMS FOR USE IN SOLAR HEATING SYSTEMS FOR MULTI-FAMILY DWELLINGS

Prepared by

Solar Control Corporation
5595 Arapahoe Road
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Under Contract NAS8-32258 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

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15. SUPPLEMENTARY NOTES

This work was done under the technical management of Mr. James Hankins, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This document is the first quarterly report from Solar Control Corporation reflecting the progress of work from October 15, 1976, through January 15, 1977. Solar Control, under NASA/MSFC Contract NAS8-32258, is developing three identical modular control subsystems for use in solar heating systems for multi-family dwellings.

The quarterly report has been reformatted, and the pages renumbered. A limited amount of retyping has been done, and cost information removed.

17. KEY WORDS	18. DISTRIBUTION STATEMENT Unclassified-Unlimited William A. Brooksbank, Jr. WILLIAM A. BROOKSBANK, JR. Manager, Solar Heating & Cooling Proj Ofc

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Contract No. NAS 8-32258

Quarterly Report

Part I. Summary

This report details activity under the contract for the first quarterly period.

One change proposal, CP77-1, has been submitted by Solar Control Corporation (SCC) and has been accepted formally at MSFC. This addition to the contract will delay the original hardware delivery schedule about four weeks. Appropriate additions and changes to the baseline documents have been reported to the Technical Manager or are in process.

Technical status of the contract work is described. Data, curves, charts and test results are included. Also included is a forecast of activities needed for completion of the contract. One apparent remaining problem is discussed.

Part II. Contract

At the end of the first quarter year of the contract period, work and documentation for contract items is on schedule. However, the original schedule has been modified to accommodate a Change Proposal.

Change Proposal CP77-1, "Mechanical Packaging Addition', was submitted to Technical Director J. Hankins on January 19, 1977; this proposal has been informally accepted at MSFC. Baseline documents are being updated to reflect this change. The addition of CP77-1 to the contract will delay the original schedule for hardware delivery by about four weeks.

Part III. Schedules

The development plan schedule has been updated to reflect CP77-1. The milestone chart has been modified accordingly.

Development Plan Schedule

Preliminary Design Review	Completed January 6, 1977
Quarterly Review	March 30, 1977
Prototype Design Review	March 30, 1977
First Article Review	April 20, 1977
Hardware Delivery	May 18, 1977

Part IV. Technical Performance

A. General description of work

Design: Circuit design is completed and drawings showing circuits are complete. PCB layout is completed. All electronic parts are on order. The mechanical housing authorized in CP77-1 has been ordered to a commercial drawing number. However, drawings reflecting this addition are not yet completed.

Manuals: Maintenance Manuals and Installation instructions had not been completed pending acceptance of CP77-1. These are now in process and the first draft should be completed prior to the Prototype Design Review. Detailed procedures for Verification and acceptance testing are being prepared.

Prototype Design Review: This has been re-scheduled for February 23, 1977, at Solar Control Corporation in Boulder, Colorado. It is assumed this review will also cover the required Quarterly Review.

B. Forecast of activities for completion

Key items to be completed are:

1. Installation instructions (preliminary)
2. Maintenance Manual (preliminary)
3. Top assembly drawings for 75-172, 75-173, and 75-175

These items are scheduled for completion by February 15, 1977.

C. Identification of problems

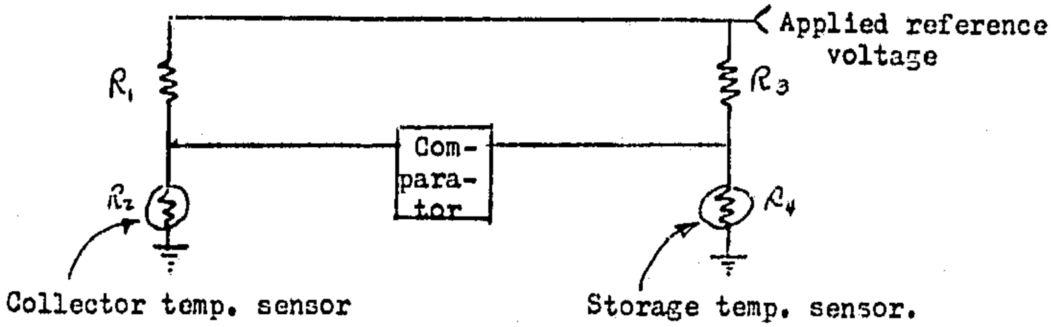
The largest problem remaining is to reach agreement with Underwriters Laboratories on the scope, schedule, and cost for UL testing and approval of the modules at 120 V. This agreement will be sought in the near future.

D. Verification Status and data.

Calculations were made to determine predicted performance of the 75-171 differential thermostat. Then calculated values were tested for the offset temperature, boil and freeze protect points. These tests covered items 1.7 (Control), 4.2 (Fail Safe Control), and 4.2.1 (System Failure Prevention) of the Verification Cross Reference Matrix. Details and results of the testing are attached.

Calculated Performance

The differential controller utilizes a bridge configuration with a thermistor temperature sensing element in each leg.* A voltage comparator inclosed across the bridge senses any imbalance of the bridge and provides a control signal when an imbalance exists. The switching point of the comparator exists at the point where the voltages are equal. Each element of the bridge illustrated below has a numerical assignment to identify it.



The voltage at the junction of a voltage divider (the junction of R_1 & R_2, and the junction of R_3 & R_4) can be described mathematically by:

$$V = \frac{(R_2)(V_{REF})}{R_2 + R_1} \qquad \text{and} \qquad V = \frac{(R_3)(V_{REF})}{R_3 + R_4} \qquad (1)$$

It is required to analyze the circuit operation at the point where it switches from one stage to the other. Since the switching point occurs where the two voltages are equal, the above equations are made equal to each other.

$$\frac{(R_2)(V_{REF})}{R_2 + R_1} = \frac{(R_3)(V_{REF})}{R_3 + R_4} \qquad (2)$$

Solving for R_2 we obtain:

$$R_2 = \frac{R_4 R_1}{R_3} \qquad (3)$$

Thus we can obtain the resistance of R_2 for any given resistance of R_1, R_3, & R_4. R_2 and R_4 represent the temperatures of collector and storage. In testing the device, a calibrated resistance is substituted for R_4, representing a given temperature (see Table I, Thermal resistance chart). The measured resistance of R_2 then related to the temperature of the collector, which can be found on the chart.

To produce an offset, R_1 is altered by the parallel resistance of the "offset resistor. The combination of the two is calculated by:

$$R_{OFF\,(COMBINATION)} = \frac{1}{1/R_1 + 1/R_{SET}} \qquad (4)$$

* The thermistor manufacturer provides a table of resistance vs. temperature.

This value is substituted in equation (3) and the value of R_2 is calculated at each extreme of the temperature span of interest by using the corresponding resistance of R_4 derived from Table I.

For example, if we desire to find the "off" point of the system when the storage is at 100° F, we convert to Centigrade:

100° F = 38° C

From the chart, we know that the storage probe resistance is 16,697 ohms. Substituting this value in equation (3) we obtain:

$$R_2 = \frac{16{,}697 \times 9130}{10\,000}$$

$$R_2 = 15244\ \Omega$$

From the chart, we see that the collector must be close to 40° C. We have a differential of (40 - 38) = 2° C or 3.6° F.

This calculation was carried out for 40° F and 180° F to establish the "off" points illustrated in Graph 1.

Similarly, a resistor is placed in parallel with the combination of R_1 and the "off" resistor to establish the "on" set point. This is calculated by:

$$R_{ON\,(COMBINATION)} = \frac{1}{1/R_1 + 1/R_{OFF\,(COMB)}}$$

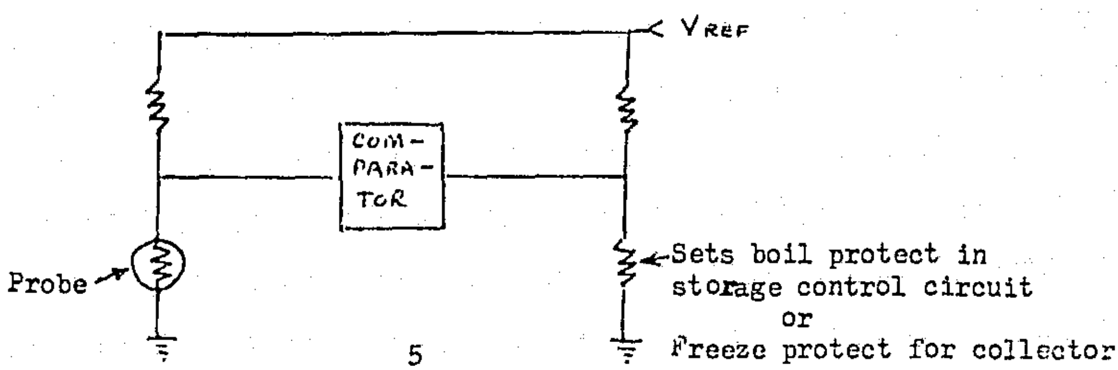
This value is plugged into equation (3) and the value of R_2 is calculated at each extreme of the temprrature span of interest ty using the corresponding resistance of R_4 derived from the table. This establishes the "on" point illustrated in graph 1.

To check linearity of the graphs, several intermediate points may be calculated using the same methods.

It should be noted that the charts show temperatures in Centigrade; conversion to Fahrenheit may be made for the convenience of the users of the graph.

Boil and Freeze Protect

The boil and freeze protect circuits operate in much the same manner as described above, except that one side of the bridge is composed of fixed resistors instead of a resistor and a temperature sen or. The trip points for these functions are set by the selection of the lower resistor (R_4). This is accomplished by using the corresponding resistance of the desired temperature from the chart.



Testing

It is desired to test whether the control "ON" and "OFF" points operate as intended. Since actual temperature changes for the probes would be awkward, and might tend to introduce error, a resistance substitution method was used. Precision resistors were substituted for the probes, the value of the resistor directly relating to temperaturse according to published charts of the manufacturer. (Guaranteed accuracy of the thermistors is 1%.)

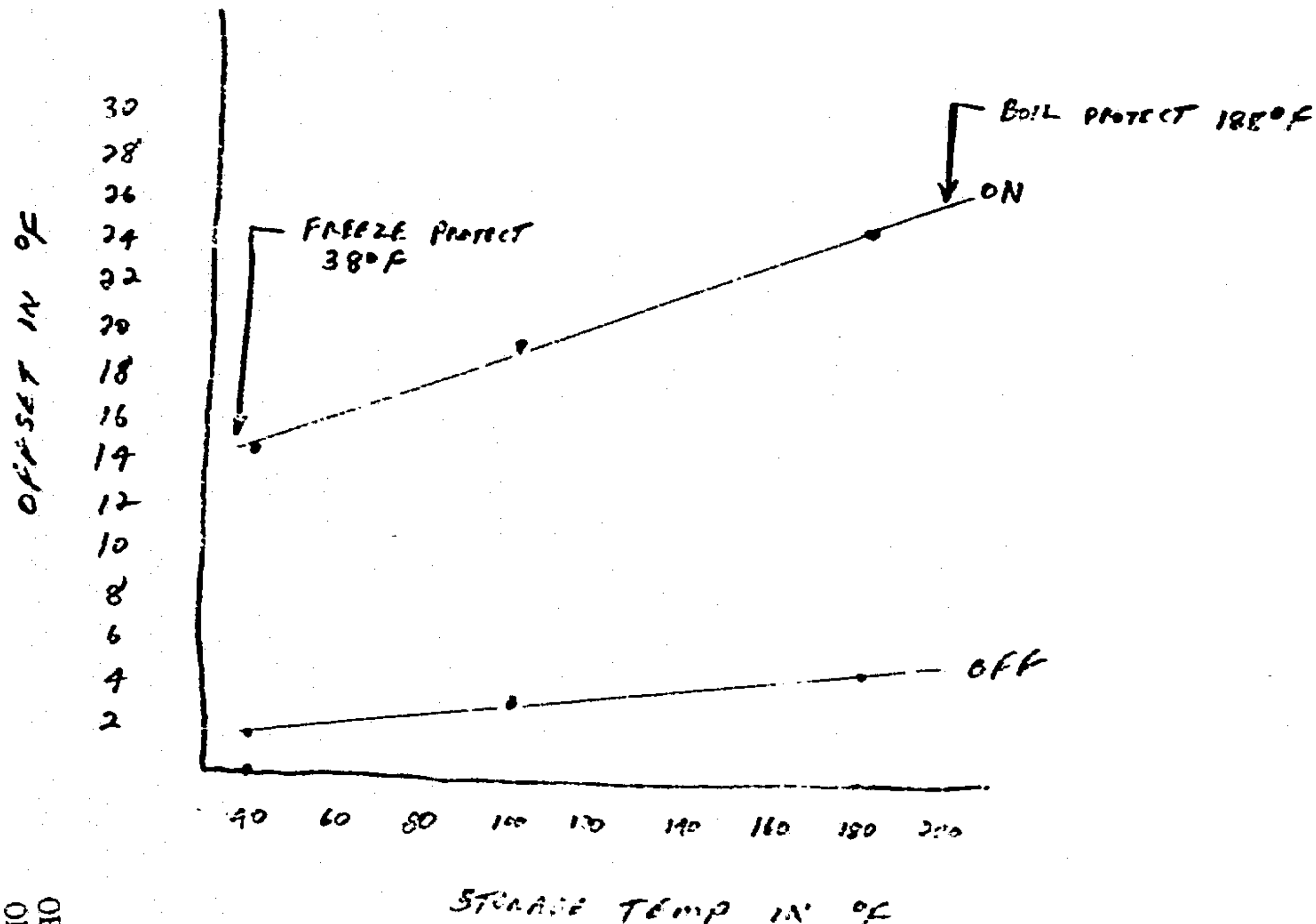
The "on and "off" trip points were checked at three points: 40°F, 100°F, and 180°F. Circuit performance was verified at each point by checking it three times at each temperature.

The collector probe resistance was run down to 32° F to check for freeze control and the storage probe resistance was run up to 210° F to check for boil protect.

This test was carried out with the controller at three different temperatures: 40°F, 72°F (room temperature), and 140°F. In each case, the controller was held at that temperature for two hours prior to and during the test. Again, the "on" and "off" points were tested three times in each case.

Test results

No measurable deviation from the predicted performance was observed in any of the above tests.



75-171 CONTROLLER

GRAPH #1

INTERCHANGEABLE CURVE-MATCHED THERMISTOR

COLOR CODE [illegible]

[illegible] 30,000 OHMS AT 25 °C [illegible]

-40	1,204,600	37	17,441	114	1,085.9
-39	1,125,000	38	16,697	115	1,054.1
38	1,051,100	39	15,989	116	1,023.3
37	982,390	40	15,314	117	993.53
36	918,590	41	14,672	118	964.74
35	859,280	42	14,059	119	936.91
34	804,130	43	13,475	120	909.99
33	752,820	44	12,919	121	[illegible]
32	705,070	45	12,388	122	858.76
31	660,620	46	11,881	123	834.39
30	619,200	47	11,398	124	810.81
29	580,620	48	10,937	125	787.98
28	544,650	49	10,497	126	765.89
27	511,100	50	10,077	127	744.50
26	479,810	51	9,676.0	128	723.78
25	450,610	52	9,292.8	129	703.73
24	423,340	53	8,926.7	130	684.31
23	397,870	54	8,576.9	131	665.49
22	374,070	55	8,242.5	132	647.27
21	351,830	56	7,922.7	133	629.60
20	331,030	57	7,617.0	134	612.50
19	311,580	58	7,324.6	135	595.91
18	293,370	59	7,044.8	136	579.83
17	276,330	60	6,777.1	137	564.26
16	260,370	61	6,520.9	138	549.15
15	245,420	62	6,275.6	139	534.50
14	231,410	63	6,040.8	140	520.30
13	218,280	64	5,815.9	141	506.52
12	205,960	65	5,600.4	142	493.16
11	194,410	66	5,394.0	143	480.19
10	183,560	67	5,196.2	144	467.61
9	173,380	68	5,006.6	145	455.41
8	163,820	69	4,824.8	146	443.57
7	154,840	70	4,650.5	147	432.07
6	146,400	71	4,483.4	148	420.91
5	138,470	72	4,323.0	149	410.08
4	131,000	73	4,169.1	150	399.56
3	123,990	74	4,021.4		
2	117,380	75	3,879.7		
1	111,160	76	3,743.7		
0	105,310	77	3,613.0		
1	99,792	78	3,487.5		
2	94,596	79	3,367.0		
3	89,698	80	3,251.2		
4	85,060	81	3,140.0		
5	80,725	82	3,033.0		
6	76,616	83	2,930.2		
7	72,738	84	2,831.3		
8	69,077	85	2,736.2		
9	65,620	86	2,644.8		
10	62,354	87	2,556.8		
11	59,268	88	2,472.2		
12	56,352	89	2,390.7		
13	53,594	90	2,312.3		
14	50,986	91	2,236.8		
15	48,519	92	2,164.2		
16	46,184	93	2,094.2		
17	43,974	94	2,026.8		
18	41,882	95	1,961.8		
19	39,900	96	1,899.3		
20	38,022	97	1,839.0		
21	36,242	98	1,780.8		
22	34,556	99	1,724.8		
23	32,958	100	1,670.8		
24	31,439	101	1,618.7		
25	30,000	102	1,568.4		
26	28,634	103	1,520.0		
27	27,338	104	1,473.2		
28	26,107	105	1,428.1		
29	24,937	106	1,384.5		
30	23,827	107	1,342.5		
31	22,771	108	1,301.9		
32	21,768	109	1,262.7		
33	20,814	110	1,224.9		
34	19,907	111	1,188.3		
35	19,044	112	1,153.0		
36	18,223	113	1,118.9		

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