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S8DR TEMPERATURE SWITCH

DEVELOPMENT AND TESTING

AEC Research and Development Report

ATOMICS INTERNATIONAL

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S8DR TEMPERATURE SWITCH

DEVELOPMENT AND TESTING

By

J. L. POWERS

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ABSTRACT

A temperature switch is described which operates in conjunction with a platinum resistance temperature detector to provide the input signals to control the SNAP 8 Reactor. The results of a testing program which demonstrated the suitability of the device for the SNAP Developmental Reactor (S8DR) use are also described.

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I. INTRODUCTION

The magnetic amplifier temperature switch described in this report was designed to meet the stringent requirements of high accuracy and reliability and long life in a severe environment. The need for resistance to nuclear radiation, in flight application, was one of the considerations which led to the choice of a magnetic amplifier for this application.

The input to the temperature switch is a platinum resistance temperature detector (RTD) which is placed in the NaK outlet coolant line of the S8DR Reactor. At the normal operating temperature of the S8DR Reactor, the resistance of the RTD is in the range of 80 ohms ($\sim 1200^{\circ}\text{F}$) to 88 ohms ($\sim 1400^{\circ}\text{F}$). A decade box was used to simulate the resistance of the RTD. The decade box is adjustable in increments of 0.01 ohm, which corresponds to a temperature change of 0.25°F at the S8DR operating temperature of 1340°F .

The test results reported are those obtained from the S8DR temperature switch stability test, thermal cycle test, input voltage and frequency variation test, time response test, switch set-point range adjustability and resolution test, and the results of 8400 hr of the still-continuing 12,000-hr switch endurance test. During these tests, performance was within design requirements. Throughout the test program the temperature switch switch-point hysteresis never exceeded the 0.06 ohm (1.5°F) limit and remained nominally at 0.03 to 0.04 ohm. The switch-point stability remained well below the ± 0.08 ohm ($\pm 2^{\circ}\text{F}$) limit. The temperature switch time response for a 0.40 ohm step was within the 1-sec limit under all conditions. The temperature switch range adjustability surpassed the required deadband and temperature range adjustability requirements. The temperature switch switch-point resolution requirement of 0.01 ohm (0.25°F) was also met.

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Figure 1. S8DS Temperature Switch

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Figure 2. S8DS Temperature Switch with Cover Removed

II. DESIGN AND OPERATION

The temperature switch, shown in Figures 1 and 2, operates with the platinum RTD shown in Figure 3. The switch provides signals to the reactor controller whenever the reactor outlet coolant temperature, as measured by the the RTD, departs from the established temperature deadband. The temperature switch utilizes the RTD as an element of a dual resistance bridge shown in block diagram form in Figure 4. This arrangement provides two distinct null conditions, corresponding to the preselected high and low temperature limits. The temperature limits are established by adjusting the dual bridge network constants.

Each of the two magnetic amplifier inputs shown schematically in the dual-bridge network of Figure 5 is amplified by a stage of linear preamplification followed by a relay driver stage. The preamplifier is a push-pull differential design, while the relay driver stage is a single-ended amplifier. Circuit stability is enhanced by the use of magnetic amplifiers throughout. The amplifier channels are null-sensitive, that is, the relays are energized as the input crosses through zero. One channel responds to a positive voltage while the other channel responds to a negative voltage.

When the RTD temperature is within the established temperature deadband limits, the dual-bridge network develops two finite output voltages which are applied respectively to the high and low amplifier channels. The output voltages are of sufficient amplitude and the proper polarity to maintain the output relays in the de-energized state. If the RTD temperature approaches either preset limit, the corresponding output voltage of the dual-bridge approaches null. The occurrence of a null, or zero crossing, causes the appropriate output relay to be energized. It remains energized as long as the RTD temperature remains outside the temperature deadband. The opposite relay is maintained in the de-energized state by the increased voltage appearing at the other dual-bridge output. Since the critical functions of the circuit occur at signal null, the switch points are effectively independent of supply voltage variations, amplifier gain and ambient temperature.

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Figure 3. S8DS Resistance Temperature Detector

Figure 4. Temperature Switch Block Diagram

Figure 5. RTD Dual-Bridge Schematic

The switch is designed to meet the following requirements:

Switch Point Deadband Width	0.72 to 2.96 ohms (18 to 75° F)
Switch Point Range	80 to 88 ohms (1200 to 1400° F)
Switch Point Resolution	0.01 ohm (0.25° F) minimum
Switch Point Hysteresis	0.06 ohm (1.5° F) maximum
Switching Time Response	1.0 sec maximum for 0.4 ohm (10° F) resistance step through the switching point.
Switch Point Stability	Within ± 0.08 ohm ($\pm 2^\circ$ F) for 12,000 hr, under 50 to 120° F temperature environment with inputs of $115 \pm 1\%$ v ac, 400 Hz $\pm 0.5\%$ and 28 v dc $\pm 1\%$.

III. DEVELOPMENTAL EVALUATION TESTS

The setup for the developmental evaluation thermal cycle and parametric electrical test and the endurance test is shown schematically in Figure 6. Two temperature switches are used in each test for a total of four temperature switches. (On one of the endurance test switches, provision to cycle the switch through the lower switch point once each hour was added.) Decade boxes were used to simulate the resistance of the RTD's. Each box is adjustable in increments of 0.01 ohm, which corresponds to a temperature change of 0.25°F at the S8DR operating temperature of 1340°F .

The endurance test was started on May 10, 1966 and, as of May 1, 1967, had completed 8400 hr of operation. The switch thermal cycle and parametric electrical test was started on July 1, 1966 and was completed on November 2, 1966. Each of the individual tests and results is discussed.

A. TEMPERATURE SWITCH THERMAL CYCLE AND PARAMETRIC ELECTRICAL TEST

The first test was a stability test at 120°F . The switches were initially adjusted at room temperature to have a low pull-in of 83.24 and 83.20 ohms, and a high pull-in of 84.52 and 84.70 ohms. The test chamber temperature was raised to 120°F , and the ac and dc voltages were held constant at 115 v ac at 400 Hz and 28 v dc, respectively. This test was conducted for 800 hr during which the decade resistance was varied to operate the switch through each switch point once every 100 hr. Neither the low nor high pull-in switch points varied more than +0.01 ohm (0.25°F) or -0.05 ohm (1.25°F) for either switch. Likewise the switch point hysteresis never exceeded 0.06 ohm (1.5°F) for either switch.

For the second test, the test chamber temperature was lowered to 50°F , still holding the ac and dc voltage constant, and was held at 50°F for 500 hr. Again the switches were operating through both switch points once every 100 hr. Neither the low nor high pull-in switch points for either switch varied more than +0.02 ohm (0.50°F) or -0.03 ohm (0.75°F) from the initial room temperature switch point. The switch point hysteresis for either switch did not exceed 0.04 ohm (1°F).

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Figure 6. Temperature Switch Setup

The third test consisted of 50 thermal cycles between 50 and 120°F. The ac and dc voltages were held constant at 115 v ac, at 400 Hz, and 28 v dc, respectively. High and low switch point readings were taken after every 10 thermal cycles. Both the low and the high pull-in switch points remained within ± 0.03 ohm ($\pm 0.75^\circ\text{F}$) of the original room temperature settings for each switch. The switch point hysteresis for either switch never exceeded 0.04 ohm (1°F).

The fourth test was a parametric electrical and time response test. During this test the test chamber was 50, 80, and 120°F; the dc voltage was 27, 28, and 29 v dc; the ac voltage was at 110, 115, and 120 v; and the ac frequency was at 398, 400, and 402 Hz for 18 different combinations of temperature, ac voltage, ac frequency, and dc voltage. The time response for each switch was taken for a 0.4 ohm (10°F) step change of simulated RTD resistance at each of the 18 combinations and was always approximately 1 sec. The ac current requirement, which was monitored throughout the test, never exceeded 40 mamp rms for each switch. The 18 low and high pull-in switch points varied no more than ± 0.02 ohm ($\pm 0.50^\circ\text{F}$) from the initial switch point settings at the beginning of the test. The switch point hysteresis on either switch never exceeded 0.04 ohm (1°F).

The fifth test was a switch point range adjustability and resolution test. During this test the test chamber temperature was held at 80°F and, the ac and dc voltages at 115 v ac, at 400 Hz, and 28 v dc, respectively. To demonstrate that the switch could be adjusted over the required switchpoint range of 1200°F (80 ohms) to 1400°F (88 ohms), that the deadband could be adjusted over a range of 18°F (0.72 ohm) to 75°F (3.00 ohms), and that a resolution of 0.01 ohm (0.25°F) could be obtained, six low pull-in resistance values were selected and six high pull-in resistance values were selected. Using these six low pull-in values and six high pull-in values, each temperature switch was adjusted to provide the eight different combinations of deadband width and absolute temperature shown on Figure 7. (These combinations covered a total switch-point adjustment range from 1175 to 1425°F — 79.00 to 89.00 ohms — with deadband widths of 18 and 75°F). The 0.01-ohm resolution was met in all cases with careful adjustment of the "Hi," "Lo," and "Cal" trimpots. Hysteresis in all cases never exceeded 0.04 ohm (1°F).

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Figure 7. Switch Point Range and Deadband Adjustability Test Data

B. TEMPERATURE SWITCH ENDURANCE TEST

This test is a scheduled 12,000-hr endurance test. The switches were initially adjusted for a low pull-in resistance of 83.25 ohms and a high pull-in resistance of 84.75 ohms. During the first 1000 hr, the test chamber temperature was held at 120°F. After 1000 hr at 120°F, the temperature was lowered to room temperature and remained at room temperature for the completion of the test. The ac and dc voltages were held constant at 115 v ac at 400 Hz and 28 v dc, respectively, throughout the test except for a check at zero and 1000 hr, when the ac voltage was varied to 110 v ac at 400 Hz, 115 v ac at 400 Hz, and 120 v ac at 400 Hz; and the dc voltage varied to 26.5 v dc, 28 v dc, and 29.5 v dc for additional checking of the switch point settings. The switches were operated through both switch points by varying the decade resistor at 250, 500, 750,

and 1000 hr and once every 500 hr thereafter. Throughout the 8400 hr of testing completed to date on each switch, neither the low nor high pull-in switch points have varied more than +0.02 ohm (0.5° F) or -0.06 ohm (1.5° F) from the initial switch set point. The switch point hysteresis for either switch never exceeded 0.06 ohm (1.5° F).

IV. CONCLUSIONS

All test data taken to date indicate that the temperature switch is suitable for S8DR use. In 8400 hr of testing its performance has not deviated from the design requirements. The test data show no trends of increasing error as a function of time, temperature cycling, or input power frequency or voltage. Graphs of the data are not presented because each curve becomes a straight line of zero slope with data points randomly departing from that line by amounts on the order of experimental error.