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NAVY DEPARTMENT  
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Report of

Tests on Mercury-in-Glass Thermostats  
in Circuit Employed in Model LD-2  
Equipment.

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## AUTHORIZATION

1. This problem was authorized by reference (a) and the governing specifications are listed as reference (b).

Reference: (a) BuEng. ltr. S67/40(12-6-W8) of 10 December 1934.  
(b) Specifications RB 13A 486B.

## OBJECT OF TESTS

2. The object of the tests is to determine whether satisfactory thermostat life is assured under conditions of operation in the Model LD-2 equipments; whether the sample thermostats meet all but the dimensional requirements of reference (b); also, if the necessary accessories used in these tests, such as relays and series resistors, are satisfactory for continuous service.

## ABSTRACT OF TESTS

3. The thermostats were tested for accuracy of calibration at the operating temperature of 50° C., sensitivity, the effect of shock, degree of recession of the mercury column at -10° C., the degree of extension of the column at 100° C., and other requirements (where possible) of reference (b).

## Conclusions

(a) The six Precision Thermometer and Instrument Company thermostats covered by this report comply with specifications, reference (b), so far as could be determined, except for lack of accuracy in two instances of  $0.01^{\circ}$  and  $0.02^{\circ}$  C. respectively, and a lack of sensitivity in one instance of  $0.01^{\circ}$  C., and one separated mercury column during test in the Model LD-2 type of circuit.

(b) The Precision Thermometer and Instrument Company thermostats operated in the type of heat control circuit used in the Model LD-2 equipments over 300,000 operations. One thermostat developed a separated mercury column, but was still operative after the column was joined.

(c) Two Collins Instrument Company thermostats which had previously been given a life test also operated over 300,000 times in the same Model LD-2 circuit, with no indication of deterioration.

(d) One of the relays supplied by the General Radio Company was unsatisfactory in operation after about 600,000 operations due to the armature sticking to the pole piece.

### Recommendations

(a) It is recommended that the Precision Thermometer and Instrument Company's thermostats as covered by this report be approved for general use in the Naval Service and for particular use in the relay circuits incorporated in the Model LD-2 equipments, inasmuch as the failures to meet all requirements of the specifications are not serious.

(b) It is recommended that the relays used in the Model LD-2 equipments be modified to prevent the armature from making actual contact with the pole piece, in order to guard against failure of the relay to open the heater circuit after extended operation.

#### DESCRIPTION OF MATERIAL UNDER TEST

4. The material under test consists of six mercury-in-glass thermostats of the straight type of smaller dimensions than specified in reference (b), and having an operating temperature of 50° C. The dimensions are as follows:

	<u>Length</u>	<u>Diameter</u>
Mercury reservoir or bulb	13/16 inches	0.238 inches
Tip of bulb to first contact ring	2-5/8 "	
Tip of bulb to second contact ring	1-1/16 "	
Overall dimensions of stem	3-1/2 "	0.217 "
Contact rings	5/32 "	1/4 "
Distance between contact rings	7/32 "	
Total length of thermostat	4-5/16 "	

The tip of these thermostats (opposite to that of bulb) tapers to about 3/32 inch in 7/8 inch of length. Twelve strands of twisted copper wire of B&S gauge No. 40 constitute the two flexible leads to which spade clips are soldered for connecting the thermostat in circuit. These thermostats are of the Precision Instrument Company's manufacture and are numbered 5477, 5478, 5480, 5481, 5484 and 5487.

#### METHOD OF TEST

5. The operating temperatures and sensitivities were determined by comparison with a precision standard thermometer calibrated in hundredths of a degree Centigrade. Each thermostat in turn was closely associated with the precision thermometer and both bulbs immersed in a small beaker of pure mercury. The excess of applied heat over and above that necessary to reach the operating point of the thermostat was held to a minimum in each case. In this manner the sensitivities and the operating temperatures were measured simultaneously.

6. The life tests were made in a special circuit furnished by the General Radio Company, and is shown on Plate 1. An alternating voltage supply of 110 volts is arranged in series with a fixed resistor of 4000 ohms, and a paralleled connection of the special relay (single contact) and thermostat. The effective alternating current (i) passed by the resistor (R) of 4000 ohms when the thermostat is closed is 29 milliamperes. The effective current through (R) in series with the relay when the thermostat is open is 13 milliamperes. Two of these circuits were set up, one operating by the conventional method of coupling the thermostat to an electric light bulb, the light circuit making and breaking as the thermostat opened and closed, and the other consisted of the more recent electromagnetically operated light shutter, described in NRL Report No. R-1099. The speed of operation of the latter method over the former is of the order of five to one.

7. The effect of acceleration was determined by testing the instruments in a centrifuge.

#### DATA RECORDED DURING TESTS

8. The data recorded during tests are shown in Table 1.

#### PROBABLE ERRORS IN RESULTS

9. The precision thermometer used is of the Beckmann type and according to the Bureau of Standards calibration is accurate to  $0.01^{\circ}$  C.

10. Errors in the measurement of acceleration by the hand centrifuge are not greater than 10%.

#### RESULTS OF TESTS

11. These thermostats were tested and inspected (where possible) to determine compliance with every applicable paragraph of reference (b). Since there have been no specifications written relative to their physical shape and size, these data have been taken and listed under "MATERIAL UNDER TEST." All operational characteristics were measured and appear in Table 1.

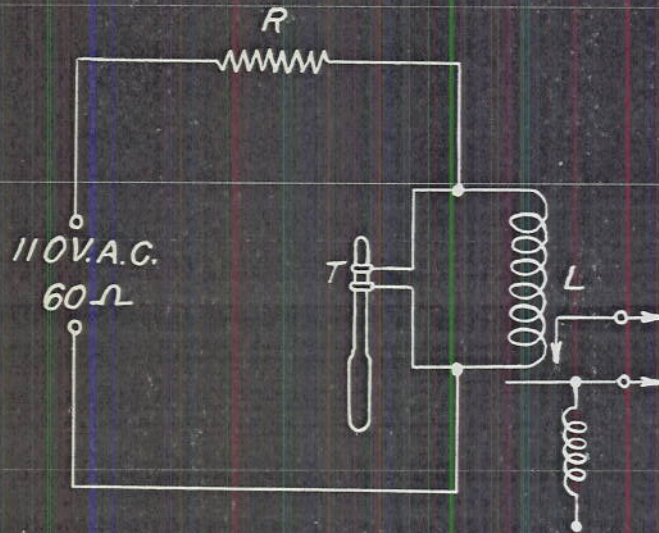
12. While the subject tests literally covered only the thermostats, the operation of the relay as submitted by the General Radio Company was also considered. This relay is a Struthers Dunn type CS 12030, single contact, for 110 volts a.c. operation. This relay is admirably suited to this type of circuit, but after about a week of continuous service, the armature began to stick badly to the pole piece. The probabilities are that when the relays are finally assembled, a sufficient amount of oxidation, intentional or otherwise, or a thin coat of lacquer, is placed over the pole piece of the electromagnet and the resulting isolation of the pole from physical contact with the armature is sufficient to withhold permanent magnetization from the armature. However, after about 624,000 contacts of the relay, this thin layer wore away and the armature was free to make intimate contact with the pole, resulting in the armature becoming permanently magnetized, and causing continued sticking of the armature to the pole piece. A cigarette paper of 0.001 inch thickness introduced between the pole and armature obviated the trouble. This same trouble may be encountered with this relay in service.

13. Thermostats No. 5478 and No. 5480 failed in the test for operating temperature, being too low in temperature by  $0.02^{\circ}$  C. and  $0.01^{\circ}$  C. respectively. Thermostat No. 5487 failed to pass the sensitivity test by  $0.01^{\circ}$  C. Thermostat No. 5484 failed completely on the life test after 23,000 cycles had been reached. The mercury column separated and allowed the thermostat to operate at a higher temperature than intended. This column was reunited and the thermostat was again put under life test until 195,697 cycles were reached, when it was removed on account of its very slow period of operation in order that the tests of other units might be expedited. Thermostat No. 5480 was likewise removed after 79,010 cycles for the same reasons. Thermostat No. 5487 was the only unit tested by the old method of life testing; its period was 0.5 cycle per second at maximum speed, but slowed down to 0.4 cycle. Thermostat No. 5478, after the indicated life tests, had a final operating temperature of  $0.01^{\circ}$  C. below the tolerance limits of  $0.05^{\circ}$  C.

TABLE 1.

<u>Make</u>	<u>No.</u>	<u>Initial Operating Temperature</u>	<u>Initial Sensitivity</u>	<u>Life Test in Cycles</u>	<u>Final Sensitivity</u>	<u>Final Operating Temperature</u>	<u>Approximate Operating Frequency</u>
Precision	5477	49.99° C.	0.01° C.	301,367	0.06° C.	49.99° C.	0.9 cy/sec.
"	5478	49.92°	0.01°	322,222	0.03°	49.93°	1.8 to 0.5 cy/sec.
"	5480	49.93°	0.005°	37,650			2.3 to 1.2 "
"	5480			79,010*	0.06°	49.94°	1.1 to 0.5 "
"	5481	49.99°	0.01°	300,921	0.02°	49.94°	1.6 to 1.5 "
"	5484	49.99°	0.01°	23,000	(Failed a/c column separated)		3.2 to 0.3 " in 3 hr. 30 min.
"	5484			195,697* (Reunited)			0.7 to 0.25 cy/sec.
"	5487	49.98°	0.04°	303,785	0.04°	49.99°	0.5 cy/sec.

\* Tests discontinued - thermostat still operative.



$R = 4000 \Omega$   
 $T = \text{THERMOSTAT}$   
 $L = \text{STRUTHERS DUNN RELAY}$   
 $2.5 \text{ HENRY APPROX.}$