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NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report of Test
of
Wire Wound Fixed Resistors
Submitted by
Hardwick Hindle, Inc.

NAVAL RESEARCH LABORATORY
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WASHINGTON, D.C.

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AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letter, reference (a). The governing specifications are listed as reference (b).

Reference: (a) BuEng.ltr. S67/63/L5 (8-30-R8) of 3 September 1938.
(b) Specifications RE 13A 372J.

OBJECT OF TEST

2. The object of the test was to determine whether the wire wound resistors manufactured by Hardwick Hindle, Inc., and submitted for test comply with the requirements of specifications, reference (b), for Grade 1, Class II resistors and are suitable for Naval use.

ABSTRACT OF TEST

3. The samples were subjected to tests to determine the following:

- (a) Compliance with mechanical requirements of these specifications, including tolerances, workmanship, etc.
- (b) Size of wire.
- (c) Winding pitch.
- (d) Wire coverage.
- (e) Temperature coefficient of resistance of the wire.
- (f) Resistance with respect to the tolerances allowed. ✓
- (g) Strength of the winding tubes.
- (h) Porosity of the winding tubes.
- (i) Strength of the finished units.
- (j) Power dissipation as related to temperature rise.
- (k) Resistance to thermal shock. ✓
- (l) Resistance to effects of excessive humidity. ✓
- (m) Strength of ferrule securing.
- (n) Design acceptability of tabs and taps.

Conclusions

(a) These resistors of both Style A and Style Z comply with the governing specifications for Grade 1, Class II resistors in all respects except that they do not dissipate the required power at the specified hot spot temperature; however, this is not due to any defect in design or manufacture but is a characteristic of resistors made under these specifications.

(b) These units are well protected against humidity effects.

(c) They are suitable for Naval use as Grade 1, Class II resistors.

Recommendations

(a) It is recommended that both the ferrule and tab type resistors represented by these samples be considered suitable for Naval use.

MATERIAL UNDER TEST

4. The material under test consisted of wire wound, fixed, enameled resistors manufactured by Hardwick Hindle, Inc., and submitted for Grade I, Class II qualification under specifications, reference (b). (Grade I resistors must satisfactorily pass 9 salt water immersion cycles; Class II resistors are not to be operated at a hot spot temperature rise exceeding 100°C.)

5. The following samples were supplied:

- 6 Style A 50,000 ohm units.
- 6 Style Z 14,000 ohm units.
- 6 Style Z 14,000 ohm units with center tap.
- 1 Style A 75,000 ohm unit without protective coating.
- 1 Style Z 14,000 ohm unit without protective coating.
- 1 Style A bare winding tube.
- 1 Style Z bare winding tube.

A group of Style Z Class I samples which had been submitted for test were delivered, with the approval of the Bureau, to the manufacturer's representative who stated that an improved group of Class I samples would be submitted. These have not been received.

METHOD OF TEST

6. The temperature coefficient of resistance of the wire was determined by measuring the resistance of the units by means of a Wheatstone bridge at several temperatures between +17 and +150° C., and computing the temperature coefficient of the wire.

7. The strength of the ceramic tubes and of the finished units was determined by noting the pressure in pounds at which damage to the units occurred when they were supported within 1/8 inch of the ends and a measured pressure applied by means of a testing machine on the upper surface at the center.

8. The porosity of the winding tubes was determined by accurately weighing fragments of the bare tubes, both after they had been heated in an oven for 24 hours at 120°C. and cooled in a desiccator for one hour, and also after they had been soaked in distilled water for 100 hours and the surface wiped dry. The latter test was made within approximately three minutes of the time the specimens were removed from the water.

9. The hot spot temperature corresponding to the voltage applied for heating the resistors previous to immersion was determined by means of a calibrated thermocouple applied to the surface of the resistors at the midpoint after the power had been applied for approximately two hours.

10. The test for thermal shock consisted of heating the units to approximately their rated hot spot temperature of 125° C. by means of a source of electrical potential and transferring them immediately to a water bath maintained at a temperature of 0°C. All samples were subjected to this test.

11. In the humidity test, the units were operated for one hour at the potential corresponding to their maximum rated temperature and then immediately transferred to a salt water bath at a temperature of 100°C.; after two hours in this bath they were transferred to another salt water bath at a temperature of 0°C. The samples were removed after two hours and rinsed in fresh water, their external surfaces wiped dry and the surface moisture removed from the inside of the tube by means of an air stream applied for approximately 10 seconds to each resistor. The units were then connected to the voltage source for a 2-hour period at the end of which time their resistance was determined by the volt-ammeter method. This humidity test was repeated 11 times on the Style A units and 12 times on the Style Z units after which it was discontinued.

12. The strength of the ferrule securing was tested by applying a torque of 5 inch-pounds at the ferrules after the humidity tests had been completed. A brass strip bent at one end in the form of a loop was clamped around the ferrule by means of screws sufficiently tight to prevent rotation of the loop on the ferrule, and a known weight was applied at the proper distance along the metal strip to produce a torque of 5 inch-pounds as required.

DATA RECORDED DURING TEST

13. The data recorded during the tests, or values computed therefrom, are given under "Results of Tests" and in the appended tables.

DISCUSSION OF PROBABLE ERRORS

14. The errors in the values measured are not greater than the following:

Temperature coefficient of resistance, $\pm 5\%$.
Resistance at 20°C., $\pm .15\%$.
Strength of bare tubes and finished units, ± 5 pounds.
Gain in weight in the porosity test of bare tubes,
 $\pm .005\%$.
Hot spot temperature, $\pm 5^\circ\text{C}$.
Power dissipated at the hot spot temperature, $\pm 1\%$.
Torque applied to the ferrules, $\pm 1/2$ pound.

RESULTS OF TEST

15. As previously stated these resistors were submitted and tested for Class II qualification which limits the test potential to a value which will not produce a hot spot temperature rise in excess of 100° C. The results of tests are reported herein in the order stated in paragraph 13-1 of specifications, reference (b), and the numbers in parentheses below correspond to those used in that paragraph of those specifications.

- (1) The resistors of both styles comply with the mechanical and dimensional requirements of the specifications. The workmanship and materials appear to be of the best quality.
- (2) The size of the wire on both uncoated units was measured to be 0.0027 ± 0.0002 ", which complies with the specification requirements.
- (3) The winding pitch of the uncoated Style A unit was 0.0033", corresponding to 303 turns per inch, and that of the Style Z units was 0.0049", corresponding to 204 turns per inch. The pitch is within the limits set by paragraph 6-7 of the specifications.
- (4) The wire coverage of the uncoated units conforms to the requirements of paragraph 6-8 and 6-9 of the specifications.
- (5) The temperature coefficient of resistance of the wire on the Style A units was measured to be 0.024% and that of the Style Z units to be 0.014%. These are average values determined by measurements on two resistors of each class between the temperatures of 17 and 150°C. The upper limit set by the specifications is 0.026%.
- (6) The resistance of all units at 20°C. is well within the 5% tolerance allowed on the untapped units and that of the sections of the center tapped Style Z units is also less than 5%, although 10% variation is allowed. The values of resistance and the per cent off from the rated value are given in Table 1.
- (7) The breaking load of the Style A bare winding tube was 600 pounds, with a crack at 350 pounds. The Style Z tube broke at a load of 420 pounds.
- (8) In the porosity test the average gain in weight of the fragments of the ceramic winding tubes after soaking in water for 100 hours was only approximately 1/4 the amount allowed, as shown in Table 2.
- (9) The breaking load of two Style A finished resistors was 750 and 790 pounds respectively; that of two Style Z units

was 640 and 680 pounds respectively. This test was performed after the humidity test. As in the case of the bare winding tubes, the specifications require that the finished units withstand a pressure of 25 pounds without damage.

- (10) The Style A units were heated by the application of a potential of 1350 volts and the Style Z units by 375 volts, which values had been determined in the test of certain previous groups of resistors as the proper values for producing a temperature rise of 100°C. at the midpoint of the resistors. Measurements of the temperature of several of these units indicate that the hot spot temperature rise at the applied potentials stated above was approximately 90°C. in the case of both Style A and Style Z units. The slightly lower operating temperature of these resistors as compared with certain other makes may be due to the fact that the design of the ferrules is such as to leave a 3/4" hole in the ends of the resistor for natural ventilation. In some makes, the diameter of this hole is not greater than 3/8". With the applied potential of 1350 volts, the Style A units dissipate a power of approximately 36 watts. With the application of 375 volts, Style Z units dissipate approximately 10 watts. While these wattages are approximately only one-half those stated in Column 6 of Table 2 of the governing specifications, reference (b), the temperature rise in operation of resistors made in compliance with these specifications is not under appreciable control by the manufacturer in the selection of materials or otherwise, and the results obtained on these units are quite representative of the actual power which resistors made under these specifications dissipate under the prescribed conditions of temperature rise.
- (11) All of the samples were subjected to the thermal shock. No visible damage resulted from the sudden chilling of the heated units to a temperature of 0°C. and no measurable change in resistance was noted.
- (12) The Style A units were subjected to a momentary overload by the application of 2500 volts for a period of one minute without any apparent damage. This overload was applied after the completion of the humidity test.
- (13) The results of the salt water immersion test to determine the degree of protection afforded these units against the effects of excessive humidity are detailed in Tables 3 and 4, where the per cent change in resistance after each immersion (as referred to the value before immersion) is given. A change in resistance of 10% represents failure of a unit; the satisfactory completion of nine humidity test cycles is necessary for Grade 1 qualification. The

data presented in these two tables are summarized below.

- (a) The Style A units were subjected to eleven humidity test cycles without a single failure and with practically no change in resistance. At the end of the test, five of the six samples appeared to be in good condition, while sample number 2 had a break in the protective enamel as shown in Plate 1, which resulted from arcing during the heating period following the sixth and the eleventh immersions.
 - (b) The Style Z units were subjected to twelve immersion cycles with only one failure, and that on the eleventh immersion. All of these samples appeared to be in good condition at the conclusion of the test with practically no change in resistance as a result of the test.
 - (c) These units withstood the humidity test unusually well, and both styles qualify as Grade 1 resistors since each individual sample satisfactorily passed more than 9 salt water immersion cycles.
- (14) After the humidity test the ferrules of the Style A units withstood twice the required torque without loosening. The unique design of the ferrules is shown in Plate 1 where both assembled and disassembled views are given. The ferrule is a metal shell 0.02" thick (which is understood to be monel metal) with one end doubled back and pressed to form the spacer ring. The ferrule is lined with a ribbed tinned copper sheet which has four "ears" extending beyond the spacer ring. This assembly is pressed over the end of the winding tube and the wire of the resistor is soldered to an "ear" of the copper insert which is, in turn, soldered to the inner edge of the spacer ring (an integral part of the ferrule). This design does not require any part of the ferrule to be inserted inside the winding tube, so that the hole throughout the length of the finished resistor has the same diameter as the inside diameter of the winding tube, or 3/4", providing for the maximum amount of natural ventilation. The ceramic tube thus extends completely under the ferrule and is as long as the finished resistor except for the thickness of the ferrule shell which extends over the ends of the winding tube as shown in Plate 1. This style of ferrule construction has shown no defects under test and is considered quite satisfactory.
- (15) The tabs and taps of Style Z units are considered to be satisfactory in design and assembly. Attention is directed to the uncoated tapped unit in Plate 1 for a view of the clamp used to bind the ends of the terminal bands together in addition to the soldered contact between the ends of the band.

CONCLUSIONS

16. These resistors of both Style A and Style Z comply with the governing specifications for Grade 1, Class II resistors in all respects except that they do not dissipate the required power at the specified hot spot temperature; however, this is not due to any defect in design or manufacture but is a characteristic of resistors made under these specifications.

17. These units are well protected against humidity effects.

18. They are suitable for Naval use as Grade 1, Class II resistors.

Table 1

Resistance of Test Samples at 20° C.

<u>Sample No.</u>	<u>Style</u>	<u>Rated Kilohms</u>	<u>Measured Kilohms</u>	<u>Per Cent Off Rated Value</u>	<u>Maximum Per Cent Off of a Tapped Section</u>
1	A	50	51.46	2.9	
2	A	50	51.33	2.7	
3	A	50	51.45	2.9	
4	A	50	51.85	3.7	
5	A	50	51.35	2.7	
6	A	50	51.57	3.1	
1	Z	14.00	14.18	1.3	
2	Z	14.00	13.92	0.6	
3	Z	14.00	14.06	0.4	
4	Z	14.00	13.74	1.9	
5	Z	14.00	13.84	1.1	
6	Z	14.00	13.93	0.5	
1	Z*	13.00	12.47	4.1	4.5
2	Z*	13.00	13.00	0.0	0.1
3	Z*	13.00	13.26	2.0	2.5
4	Z*	13.00	13.14	1.1	2.1
5	Z*	13.00	13.05	0.4	0.6
6	Z*	13.00	13.23	1.8	1.9

* Center tapped units.

Table 2

Porosity Test Data on Winding Tubes.

Style of Tube	Fragment No.	Weight in Grams		Gain in Weight	
		Dry	Wet	Grams	Per Cent
A	1	13.762	13.767	0.005	0.036
A	2	16.333	16.336	0.003	0.018
A	3	23.874	23.878	0.004	0.017
Mean	-----	-----	-----	-----	0.024
Z	1	7.952	7.954	0.002	0.025
Z	2	7.571	7.574	0.003	0.040
Z	3	9.214	9.217	0.003	0.032
Mean	-----	-----	-----	-----	0.032

Maximum gain in weight allowed - 0.10%.

Table 3

Effect of Salt Water Immersion on Resistance
of Style A, Class II Resistors.

Sample No.	Per Cent Change in Resistance After Number of Immersion Cycles Shown Below -										
	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	+4.0*	0	0	0	-1.9	0*
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	-1.9
6	0	0	+2.0	0	0	0	0	0	0	0	-1.9

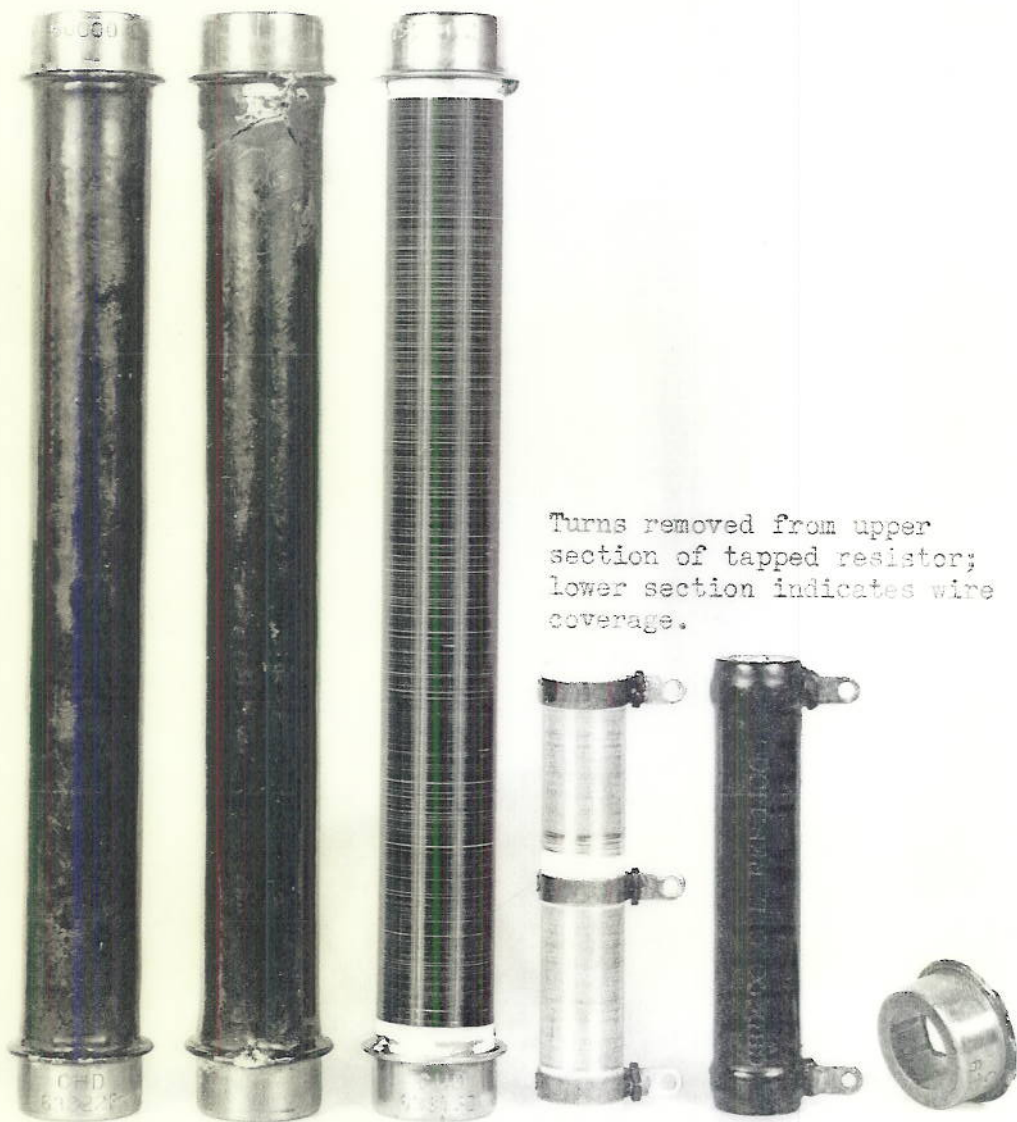
* Current through No. 2 resistor unsteady during heating period following sixth and eleventh immersions, and arcing burned a path part way around resistor near ferrule. See Plate 1.

Table 4

Effect of Salt Water Immersion on Resistance
of Style Z, Class II Resistors.

Sample No.	Per Cent Change in Resistance After Number of Immersion Cycles Shown Below -											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	+2.04	0	0	0	0	-0.34	0	0
2	0	0	0	0	+1.9	0	0	0	0	-0.83	0	0
3	0	0	0	0	0	0	0	0	0	-1.2	0	0
4	0	0	0	0	0	0	0	0	0	-1.5	0	0
5	0	0	0	0	0	0	0	0	0	-1.87	0	0
6	+1.9	+1.9	+1.9	+1.9	+1.9	0	0	+8.3	+4.0	+9.2	Open	Open

All resistors appear to be in good condition at end of test.



Turns removed from upper section of tapped resistor; lower section indicates wire coverage.

Photograph of Hardwick Hindle, Inc. Test Samples.