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Report
of
Test of Weston Special 15 KV
Composition Resistor.

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AUTHORIZATION

1. This work was authorized by Bureau of Engineering letter, reference (a). Other correspondence pertinent to this problem is listed as references (b) to (d).

Reference: (a) BuEng. ltr. F42-1/22(10-10-W8) of 16 June 1936.
(b) NRL Report No. R-1091.
(c) BuEng. ltr. F42-1/22/L5(8-14-W8) of 2 September 1936.
(d) L.D. Joralemon ltr. of 9 June 1936 to BuEng.

OBJECT OF TEST

2. The object of the tests was to determine if this type of composition resistor enclosed in a glass oil-filled tube is suitable for use in the Naval service as a voltmeter multiplier in place of the wire-wound resistors.

ABSTRACT OF TEST

3. The resistor was tested to determine the effect of ambient temperature, high humidity, operation at maximum rated voltage, and at a 50% voltage overload. It was subjected to some mechanical stress to determine its ruggedness.

Conclusions

(a) This 15 KV oil-filled composition resistor is considered to be unsuitable for Naval use due to its being somewhat fragile and due to the length of the warming up time required at high voltage in order to obtain sufficiently accurate voltage readings.

Recommendations

(a) It is recommended that this 15 KV resistor be considered unsuitable for Naval use as a voltmeter multiplier.

(b) It is recommended that the Weston Electrical Instrument Corporation be encouraged to supply additional samples of this type of resistor in a form having greater mechanical strength and designed either for more rapid cooling, or for approximately 1/2 the power dissipation per unit length, to reduce the voltage effect.

MATERIAL UNDER TEST

4. The 15 KV resistor submitted by the Weston Electrical Instrument Corporation consists of 8 composition resistor units in series enclosed in a glass oil-filled tube. Metal caps are cemented to the ends of the tube and terminate in ferrules for mounting in fuse clips. The overall length is 19 inches and the overall diameter (that of the metal caps) is 1-1/8 inches. Air or gas bubbles in the tube may be compressed upon expansion of the oil to guard against excessive pressure. The resistance of the unit is approximately 15 megohms. A photograph is appended as Plate 1.

METHOD OF TEST

5. The resistance of the unit was determined at a number of temperatures between -18 and +48°C. by the voltmeter-ammeter method with approximately 500 volts applied, to obtain its temperature coefficient of resistance. The effect of humidity was observed by subjecting the resistor to a relative humidity of 95% at a temperature of 50°C. and then allowing the temperature to drop in an effort to produce condensation, in which condition the resistance was again obtained. The resistor was operated at its maximum working voltage of 15 KV while connected in series with a Weston Model 506 voltmeter (1 m.a. full scale) and the reading of the voltmeter, the temperature of the resistor and the current through it were noted. An overload of 53% in voltage was applied and the approximate temperature observed. The unit was pressed into and pulled out of stiff fuse clips a number of times to determine its ability to withstand rough usage. This was in lieu of a vibration test.

DATA RECORDED DURING TEST

6. The data recorded during the test are given in the tables appended and under "Results of Test."

RESULTS OF TEST

7. The change in resistance of the unit with change in ambient temperature from -18 to +45.5°C. as determined by the voltmeter-ammeter method, 540 volts, was very slight, being only from 15.12 to 15.04 megohms or about 0.53% for a change of 66.5°C. (See Table 1 and Plate 2.) This represents a temperature coefficient of resistance of 0.008% per degree Centigrade. After being exposed to a relative humidity of approximately 95% at a temperature of 50°C. the temperature was allowed to decrease and the resistance then measured 14.55 megohms; when the unit had been removed from the humidity chamber for only two minutes the resistance measured 15.07 megohms. The effect of this excessive humidity on the measured resistance of the unit was therefore 3.4%, but since part of this may have been due to leakage between the insulated leads the result of the second humidity test given below, in which no lead leakage occurred, must be taken as more nearly correct. In the second humidity exposure the decrease in resistance was 1.4%. The resistance was always less after exposure to high humidity, since the surface leakage is in parallel with the resistor itself.

8. The resistor was subjected to a voltage of 23 KVs for about five minutes which is an overload of approximately 135% in dissipated power. The surface temperature was not accurately measured but was estimated to be about 70°C. In this overload test the bubbles in the oil were compressed into very small volume.

9. The unit was forced into tight fuse clips by pressure over the ferrules and also was pulled out by applying pressure at the ferrules a considerable number of times. These fuse clips were not perfectly aligned but one was free to turn into alignment when the ferrule engaged it. This treatment was considered to be representative of that which a resistor might encounter in the service. The unit was not subjected to a vibration test. After this treatment and the overload power test, the glass tube was held in one hand and a ferrule was given a slight twisting moment with the fingers of the other hand. The ferrule was found to turn and oil began to leak from the tube. Examination showed that the glass tube had cracked completely around its periphery just inside the metal end cap. It is not known whether the glass was fractured by pressing the resistor into the clips or as a result of the pressure in the tube during the voltage overload test. It is certain that the tube must have been defective when the end was twisted off with the hands.

10. With the oil about one inch below the end cap (when the unit was held vertically) the resistor was now subjected to high d.c. potentials (9 to 15 KVs) with results as follows:

Test #1. The potential applied was approximately 9 KV and the resistor was mounted in the vertical position. The resistance as measured by the voltmeter-ammeter method immediately upon the application of the potential was 10.0 megohms and it decreased continuously in the next 40 minutes to 7.9 megohms. The upper end of the resistor was very hot while the lower end was practically at room temperature.

Test #2. The resistor was mounted in a horizontal position with the broken end taped to the glass tube to prevent further loss of oil. The resistor was allowed to cool three hours after which 12,000 volts were applied. The resistance was now 9.75 megohms which decreased in an hour to 9.56 megohms or about 2%. The voltage was now raised to 15 KVs and after the current and the temperature had stabilized a Weston Model 506 voltmeter (one m.a. full scale) in series with the resistor was shunted by a value of resistance sufficient to make the instrument read full scale at 15 KV.

Test #3. The next day a potential of 15 KVs was applied for a period of one hour. The reading of the Model 506 voltmeter, the current through the resistor and the surface temperature of the center of the glass tube were recorded, together with the time after the application of the potential. The results of this test are tabulated in Table 2 from which it will be

observed that the resistance decreased from 11.45 to 11.20 megohms, or 2.2%. The reading of the Model 506 voltmeter increased 2.8%, as well as could be read from the scale of the instrument. The surface temperature increased from 32 to 63°C. The resistor was now dissipating 20 watts whereas if its resistance had been 15 megohms as rated, the power would have been only 15 watts.

11. The resistance of the unit when later measured at room temperature at a potential of 230 volts was 14.4 megohms when held in a vertical position at 13.6 megohms when held in a horizontal position. Due to leakage the oil was now approximately two inches below the metal end cap. Petrolatum was added to fill the tube up to the metal cap and the resistance now measured 14.4 megohms regardless of the position of the tube.

12. No definite explanation is offered for the discrepancy between the very low temperature coefficient of resistance of the unit as determined by heating and cooling it in a temperature control chamber and measuring the resistance at low voltage, as shown in Table 1, and the 2% change in resistance noted when a high voltage was applied to the resistor as shown in Table 2. The following are possible explanations: (a) The temperature coefficient of resistance shown in Table 1 and Plate 2 may be lower than the actual value due to the measured resistance at low temperatures being reduced somewhat by the surface leakage resulting from high relative humidity in the enclosed chamber; (b) the resistor elements may have been heated to a much higher temperature than that measured on the surface of the glass tube; (c) the properties of the resistor may have been radically changed by the loss of some of the cooling oil and the high voltage tests may not be indicative of the action of the resistor in its undamaged state.

13. In considering (c), above, attention is directed to the fact that the manufacturer's representative in reference (d) recommends that the resistor and the meter used in series with it be allowed to come up to operating temperature, which should require between 15 and 30 minutes before observations are taken.

14. The results of the tests may be summarized as follows:

- (a) The temperature coefficient of resistance of the unit is small.
- (b) The effect of excessive humidity is appreciable, the resistance being lowered at least 1.4%.
- (c) The unit is believed to be slightly fragile for Naval use.
- (d) The unit does not overheat at its rated voltage.
- (e) After the glass tube had been broken and some oil lost, the resistance of the unit was not constant from day to day and was much lower when measured at high potential than when measured at a few hundred volts.

(f) When the unit was operated at 12 or 15 KV (with the oil slightly low) the reading of a voltmeter in series with it was approximately 2.8% higher after one hour had elapsed.

15. Comparison of this resistor with non-enclosed composition resistors such as those reported on in reference (b), as suggested in reference (a), paragraph 3, is not possible since suitable samples of these resistors are not at present available. However, under the authority contained in reference (c), samples of different resistance of several of the most promising makes of composition resistors will be obtained and tested at different power dissipations and different ambient temperatures, etc. Until that work is completed, no definite comparison can be made.

CONCLUSIONS

16. This 15 KV oil-filled composition resistor is considered to be unsuitable for Naval use due to its being somewhat fragile and due to the length of the warming up time required at high voltage in order to obtain sufficiently accurate voltage readings.

Table 1

Measured Resistance of 15 KV Resistor vs.
Temperature, at Low Voltage.

<u>Temperature</u> <u>°C.</u>	<u>Volts</u>	<u>Current</u> <u>Microamps.</u>	<u>Resistance</u> <u>Megohms</u>	
-18	532.5	35.2	15.12	
-15	534.	35.3	15.12	
- 8	525.	34.7	15.12	
+13	531.	35.2	15.08	
+25	541.	35.5	15.24	
+25	532.5	35.0	15.21	
27	538.5	36.3	14.82	Relative humidity high.
27	535.	35.7	14.98	Relative humidity decreasing.
27	532.5	35.4	15.04	Relative humidity still decreasing.
27	527.5	34.6	15.25	
30	557.5	36.6	15.26	
33.5	575.	37.7	15.26	
41	532.5	35.3	15.08	
41.5	539.	35.6	15.14	
46	527.5	35.0	15.08	
46.5	533.5	35.4	15.07	
47.5	532.5	35.4	15.04	
48.5	532.5	35.4	15.04	

Table 2

High Voltage Test Data on 15 KV
Resistor.

Note: Data obtained after some oil had leaked from broken resistor tube. Model 506 meter (Column 3) shunted to read 15 KV after 15 KV had been applied one hour. Resistance then was 9.4 megohms. Data below taken next day beginning with resistor at room temperature.

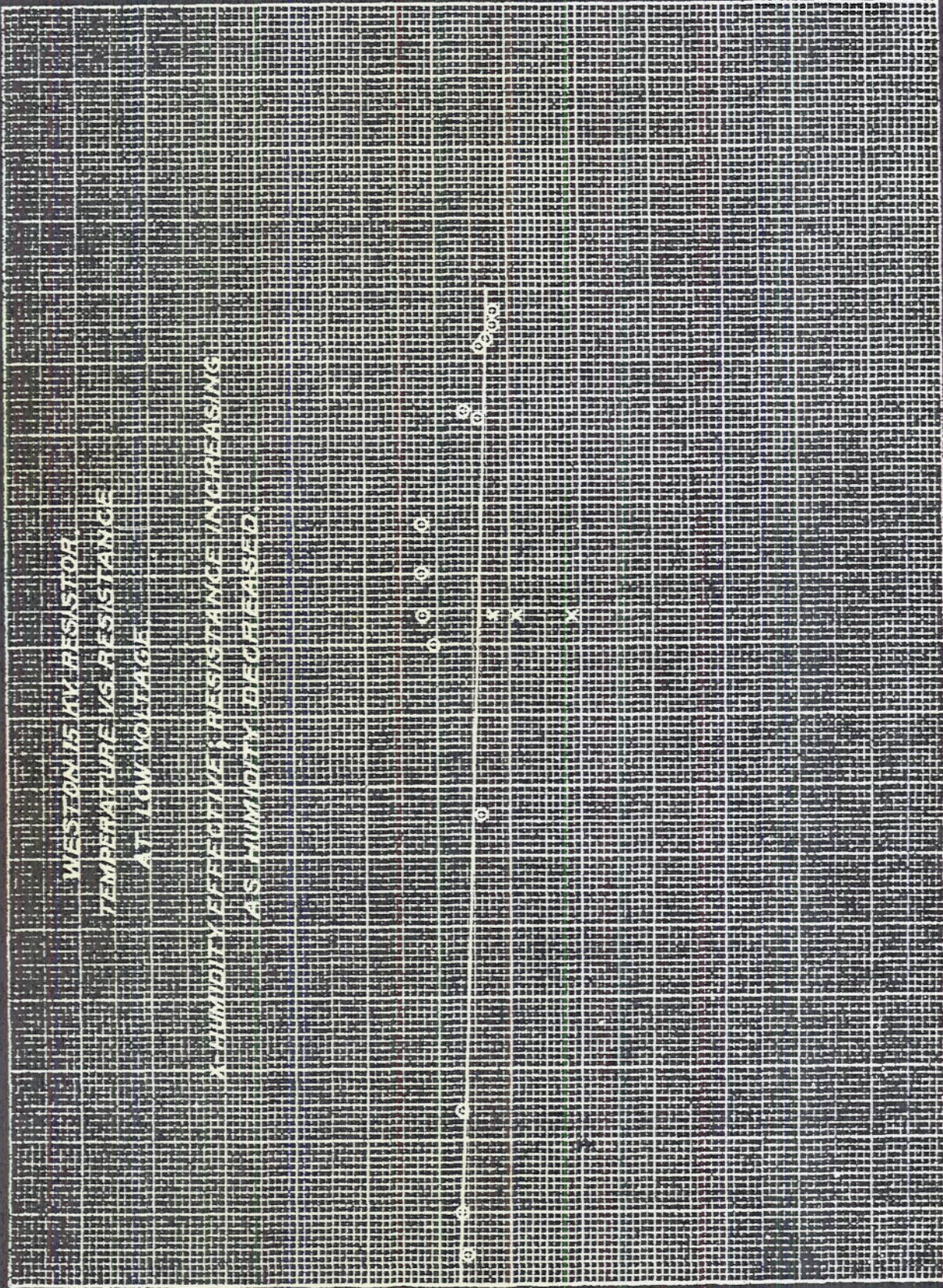
<u>Mins. After</u> <u>Voltage</u> <u>Applied</u>	<u>Kilovolts</u> <u>Applied</u>	<u>Model 506</u> <u>Meter Read-</u> <u>ing (KV)</u>	<u>Current</u> <u>(M.A.)</u>	<u>Resistance</u> <u>(Megs.)</u>	<u>Temperature</u> <u>of Resistor</u> <u>(°C.)</u>
0	-	-	-	-	32
1	15.00	12.24	1.31	11.45	32
3	15.00	12.24	1.32	11.37	35
6	15.00	12.24	1.31	11.45	40
9	15.00	12.30	1.32	11.37	43
13	15.00	12.24	1.31	11.45	46
18	15.00	12.35	1.32	11.37	52
21	15.00	12.42	1.33	11.28	54
25	15.00	12.48	1.33	11.28	56
28	15.00	12.54	1.33	11.28	58
30	15.00	12.48	1.33	11.28	59
34	15.00	12.54	1.34	11.20	60
37	15.00	12.54	1.34	11.20	60
40	15.00	12.54	1.34	11.20	61
44	15.00	12.54	1.34	11.20	61
49	15.00	12.60	1.34	11.20	61
54	15.00	12.60	1.34	11.20	62
58	15.00	12.60	1.34	11.20	63
61	15.00	12.54	1.34	11.20	63

Note: Power dissipated, 20 watts.



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WESTON 15 KV RESISTOR

TEMPERATURE VS. RESISTANCE
AT LOW VOLTAGE

HUMIDITY EFFECTIVE RESISTANCE INCREASING
AS HUMIDITY DECREASES

D.C. RESISTANCE - MEGOHMS.

TEMPERATURE - °C

PLATE 2

