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Nichrome as a rheostat resistance

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-THESIS-

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NICHROME AS A RHEOSTAT RESISTANCE.

-BY-

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-FINDING AVERAGE DIAMETER-

The diameter of wire was measured a number of places with a Brown & Sharp micrometer, reading to $\frac{1}{1000}$ cm. and found to vary between 0.072 and 0.0725, the fourth figure being an approximation, and then as a check on above, and also to find an average diameter, we determined the volume of the specimen by noticing the displacement of distilled water in a calibrated tube which read to $\frac{1}{10}$ c.c., the hundredth here, also being an approximation. This volume divided by known length gives the average cross-sectional area.

Length of specimen	Water displaced.
60 cm.	0.25 c.c.

0.25 divided by 60 = 0.00417

$$\frac{\pi d^2}{4} = 0.00416$$

d = 0.0728 cm.

-SPECIFIC GRAVITY-

Diameter of wire = 0.0723 cm. = 0.0282 inches = a No.21 wire

Wire weighed on a Bung balance which read to $\frac{1}{10000}$ grms.

Method I -

Weight of wire = 1.9646 grms.

Weight of flask + water = 38.8621

40.8267

Weight of flask + water + wire = 40.5857

40.8267 - 40.5857 = 0.2410 = weight of water displaced.

1.9646 divided by 241 = 8.151 = specific gravity of alloy.

Method II-

Length of wire = 39.8 cm.(weighing 1.32245 grms.)

$$\text{Volume} = \frac{\pi d^2}{4} L = \frac{22}{7} \times \frac{1}{4} \times 0.072^2 \times 39.8$$

Volume = 0.16209

Volume x specific-gravity = Weight

0.16209 x specific-gravity = 1.32245

Specific-gravity = 8.152

-TORSION TESTS-

The torsion test was made by gripping the two ends of the specimen between jaws, one of which is fixed so as to prevent its turning, while the other one is rotated. The fixed jaw can move to a certain extent in a direction parallel to the specimen of wire being tested, but it was also so adjusted as to keep the specimen reasonably taut. The fixed jaw, by means of a crank was rotated, thus twisting the specimen. In making the tests care was taken to see that the specimen was not injured by the jaws, of the torsion testing machine.

The following results were obtained:-

Length of specimen.		No. of twists to break.
1 - - - -12	inches	- - - - - - - - - - 77
2 - - - -12	"	- - - - - - - - - - 95
3 - - - -12	"	- - - - - - - - - -113
4 - - - -12	"	- - - - - - - - - -115
5 - - - -12	"	- - - - - - - - - - 99
6 - - - -12	"	- - - - - - - - - -102
7 - - - -12	"	- - - - - - - - - -112
8 - - - -12	"	- - - - - - - - - -119

-TORSION TESTS- (Continued)

Length of specimen		No. of twists to break.
9	12 inches	80
10	12 "	92
11	12 "	87
12	12 "	103
13	12 "	115
14	12 "	98
15	12 "	102
		Average = 100

1	6 inches	55
2	6 "	60
3	6 "	57
4	6 "	53
5	6 "	50
6	6 "	61
7	6 "	47
8	6 "	40
9	6 "	47
10	6 "	47
11	6 "	33

-TORSION TEST- (Continued)

Length of specimen	No. of twists to break.
12 - - 6 inches	31
13 - - 6 "	39
14 - - 6 "	57
15 - - 6 "	62
16 - - 6 "	55
17 - - 6 "	53
18 - - 6 "	60
19 - - 6 "	59
20 - - 6 "	49
	Average = 51

Sufficient current was put through specimen wires to heat them red hot. This was continued for from four to eight hours, and then wire was cooled for about same length of time. This was kept up alternately for one week.

Following results on above specimen: -

Length of specimen	No. of twists to break.
1 - - - 12 inches	73
2 - - - 12 "	73

-TORSION TESTS- (Continued)

Length of specimen	No. of twists to break.
3 - - - 12 inches	- - - - - - - - - - - 45
4 - - - 12 "	- - - - - - - - - - - 70
5 - - - 12 "	- - - - - - - - - - - 75
6 - - - 12 "	- - - - - - - - - - - 78
	Average = 69

1 - - - 6 inches	- - - - - - - - - - - 37
2 - - - 6 "	- - - - - - - - - - - 44
3 - - - 6 "	- - - - - - - - - - - 41
4 - - - 6 "	- - - - - - - - - - - 35
5 - - - 6 "	- - - - - - - - - - - 33
6 - - - 6 "	- - - - - - - - - - - 39
	Average = 38.

Sufficient current was passed through wire to make it hot enough to char wood, and the following torsion tests noted.

-TORSION TESTS- (Continued)

Length of specimen		No. of twists to break.
1 - - - 12	inches	- - - - - - - - - - 67
2 - - - 12	"	- - - - - - - - - - 78
3 - - - 12	"	- - - - - - - - - - 56
4 - - - 12	"	- - - - - - - - - - 52
5 - - - 12	"	- - - - - - - - - - 58
6 - - - 12	"	- - - - - - - - - - 60
		Average = 62

1 - - - 6	inches	- - - - - - - - - - 49
2 - - - 6	"	- - - - - - - - - - 39
3 - - - 6	"	- - - - - - - - - - 41
4 - - - 6	"	- - - - - - - - - - 43
5 - - - 6	"	- - - - - - - - - - 35
6 - - - 6	"	- - - - - - - - - - 46
		Average = 42

-TORSION TESTS- (Continued)

The following tests were made on a number twenty-one "German-Silver" wire as a comparison between it and "Nichrome"

Length of specimen			No. of twists to break.
1	12 inches		58
2	12	"	96
3	12	"	70
4	12	"	90
5	12	"	95
6	12	"	85
			Average = 83

1	6 inches		69
2	6	"	58
3	6	"	40
4	6	"	42
5	6	"	62
6	6	"	38
			Average = 52

-TORSION TESTS- (Continued)

Sufficient current was put through a number twenty-one "German-Silver" wire to make it hot enough to char wood, and the following torsion tests noted:-

Length of specimen		No. of twist to break.
1 - - - 12	inches	- - - - - - - - - - 73
2 - - - 12	"	- - - - - - - - - - 65
3 - - - 12	"	- - - - - - - - - - 52
4 - - - 12	"	- - - - - - - - - - 59
5 - - - 12	"	- - - - - - - - - - 62
6 - - - 12	"	- - - - - - - - - - 63
		Average = 62

1 - - - 6	inches	- - - - - - - - - - 25
2 - - - 6	"	- - - - - - - - - - 38
3 - - - 6	"	- - - - - - - - - - 42
4 - - - 6	"	- - - - - - - - - - 26
5 - - - 6	"	- - - - - - - - - - 38
6 - - - 6	"	- - - - - - - - - - 50
		Average = 36

-TENSILE STRENGTH and ELONGATION-

TENSILE STRENGTH.

The method of determining the tensile strength was as follows: One end of the wire was securely fastened to an over-head beam and to the lower end was attached a pan into which test-lead was poured, till the force became great enough to produce rupture. The test-lead was afterward weighed. The first test was mainly to get the approximate tensile strength and the last two results are more nearly correct.

-ELONGATION-

The apparatus used, was a "Thos. Gray Apparatus" for measuring elongation. The same method was employed, as that used in determining the tensile strength. Enough test-lead was poured into pan till wire was stretched a certain fraction of an inch, and the test-lead, was weighed and noted each successive time. The scale read to $\frac{1}{20}$ of an inch, and the first reading is as close an approximation as possible.

-RESULTS and COMPUTATIONS for TENSILE STRENGTH-

Length of wire		Weight to produce rupture.	
Centimeters	Inches	Grams.	Pounds.
1 -- 211.7	83.346	31000	68.35
2 -- 211.7	83.346	29000	63.8
3 -- 211.7	83.346	29000	63.8

Average for tensile strength = 63.8 lbs.

Tensile strength of alloy = 100000 lbs/sq.in.

Tensile strength wrot.iron = 55000 lbs/sq.in.

-RESULTS and COMPUTATIONS for ELONGATION-

Length of wire		Weights		Elongation.
Centimeter	Inches	Grams	Pounds	
1 -- 211.7	83.346	2600	5.72	1/40 inches,
2 -- 211.7	83.346	4200	9.24	1/20 "
3 -- 211.7	83.346	7700	16.94	1/10 "

-RESULTS and COMPUTATIONS for ELONGATION- (Continued)

By Hookes' law.:

$$E = \frac{\frac{W}{A}}{\frac{l}{L}} = \frac{W\ L}{A\ l}$$

E for (1) = 30000000 lbs/sq.in.

E " (2) = 25000000 lbs/sq.in

E " (3) = 23000000 lbs/sq.in.

Average modulus = 26000000 lbs/sq.in.

Modulus for wrot.iron = 25000000 lbs/sq.in.

-TESTS for CORROSION-

Two wires through which current had been passed, one with sufficient current to make it hot enough to char wood, and the other heated red hot, were hung in a relatively dry atmosphere, and the current passed through them alternately. After a weeks time, no evidence of corrosion could be seen.

Next a coil of the first wire (a) mentioned, and a coil of Nichrome wire (b) through which no current had been passed were subjected to equally wet and dry treatment. A steam bath was arranged to furnish the wet atmosphere. After four days of the above treatment, the wire was seen to have become coated with a greenish brown substance undoubtedly the oxide of some metal in alloy. (Noticed when passing a current through "German-Silver" wire, that a dark film formed almost immediately on the wire.

Results on the two pieces of Nichrome wire.

	Weight before. Wet and dry Treatment	Weight after. Wet and dry. Treatment	Gain	% Gain.
(a)	-5.3409	5.3483	-0.0074	0.136
(b)	-5.7107	5.7205	-0.0098	0.171

-MEASUREMENT of RESISTANCE-

As a comparison, the resistance of Nichrome and "German-Silver" was measured with a Leeds Northrup Decade Testing Set, and the following resistances noted:

Length of specimen	Nichrome resist.	Resist. per mil-foot
1 - - 62.5 cm - - - -	-1.562 ohms. - - - - - - - -	597
2 - - 95.8 " - - - -	-2.420 " - - - - - - - -	605
3 - - 167.5 " - - - -	-4.220 " - - - - - - - -	-600
	Average	601

-GERMAN-SILVER-

Length	Resistance	Resist.per mil-foot.
1 - - 53.6 cm - - - -	-0.430 ohms.- - - - - - -	197
2 - - 110.0 " - - - -	-0.915 " - - - - - - -	199
3 - - 147.5 " - - - -	-1.215 " - - - - - - -	199
	Average	198

-MEASUREMENT OF RESISTANCE WITH CHANGE OF TEMPERATURE-

Resistance of specimen was taken at 24 °C, then put in the muffle of an assay furnace, where temperature was measured with a La Chatlier thermal junction, and resistance noted. The following results were obtained:

-NICHROME-

	Length of specimen	Resist. at 24 °C.	Resist. at 75 °C.	Resist. at 90 °C.	Resist. at 95°C.
1	62.5	1.562	1.593		
2	95.8	2.430		486	
3	167.5	4.220			346

-GERMAN-SILVER-

	Length of specimen	Resist. at 24 °C.	Resist. at 75 °C.	Resist. at 90 °C.	Resist. at 95 °C.
1	53.6	0.430	0.439		
2	110.0	0.915		0.939	
3	147.5	1.215			1.250

-COMPUTATION of TEMPERATURE COEFFICIENT-

Nichrome, $R_{t_1} = R_{t_2} \left(1 + a (t_1 - t_2) \right)$, $a = 0.000410$

German-Silver, $R_{t_1} = R_{t_2} \left(1 + a (t_1 - t_2) \right)$, $a = 0.000407$

-CONCLUSIONS-

Nichrome wire is a high resistance alloy, and is not appreciably effected in its resistance by changes of temperature to which it may be subjected in practice. This was shown by the low temperature coefficient obtained.

Nichrome does not deteriorate by heating, as shown by torsion-tests after current had been passed through wire. German-Silver however, becomes brittle.

Nichrome in a moist atmosphere corrodes rapidly, but in a relatively dry atmosphere, and heated red hot, no signs of oxidation or corrosion could be seen. By all results obtained as to strength, resistance etc. Nichrome is superior to German-Silver as a resistance wire.

-SUMMARY-

Diameter of wire, - - - - - - - - - 0.072 cm. = 0.0283 "

Specific-Gravity, - - - - - - - - - - 8.15

Tensile stength - - - - -- - - - - - - -1000000 lbs/sq.in

Modulus of Elasticity - - - - - - - - 86000000 lbs/sq.in.

Resistance per mil-foot - - - - - - - 601 ohms.

Temperature Coefficient - - - - - - - -0.000410

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