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GOLD-COBALT RESISTANCE ALLOYS

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ABSTRACT

Gold-cobalt alloys containing 0.75 to 5 percent of cobalt have been prepared and investigated to determine if they are suitable for use in the construction of electrical resistance standards. The temperature coefficient of electrical resistance of the alloys containing from 1.5 to 2.5 percent of cobalt is small at room temperatures, but the thermoelectric power of the alloys against copper is large. These alloys were found to be inferior to gold-chromium alloys of about the same proportions.

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I. INTRODUCTION

It has been found by Linde [1] that the electrical resistivity of gold is greatly increased by the addition of a small percentage of cobalt and at the same time its temperature coefficient of resistance is greatly decreased. Extrapolating his data, he predicted that 2 percent by weight of cobalt in gold would give an alloy with a zero temperature coefficient at laboratory temperatures. In order to determine if such alloys were suitable for use in the construction of electrical resistance standards, gold-cobalt alloys containing from 0.75 to 5 percent of cobalt have been prepared at this Bureau and their electrical properties investigated. This investigation was abandoned before completion as it was soon decided that the gold-cobalt alloys were inferior to gold-chromium alloys, which were recently described in this journal.[2] However, the data obtained were thought to be of sufficient interest to justify their publication.

II. PREPARATION OF GOLD-COBALT ALLOYS

The alloys were prepared by melting the gold and cobalt together under borax, in a graphite crucible, by means of an induction furnace. The alloys were heated to about 1,200° C and then poured into a graphite mold. It was found that the two metals did not mix very readily; so in each case the alloys were remelted and again poured into the graphite molds.

[1] J. O. Linde, Ann. Physik **402**, 52 (1931); **407**, 219 (1932).
[2] J. L. Thomas, J. Research NBS **13**, 681 (1934) RP737.

The ingots were first hot-forged into the form of rods 5 or 6 mm square. They were then cold-rolled and swaged to a diameter of 0.75 mm, after which they were drawn down to a diameter of about 0.4 mm. through sapphire dies. The material was annealed four or five times during the rolling and swaging, but it was not annealed during the drawing.

Seven of these gold-cobalt alloys were prepared and investigated. They contained from 0.75 to 5 percent of cobalt by weight, as determined by chemical analyses. Little cobalt was lost during melting and the chemical analyses checked very well with the composition as calculated from the ingredients used. The characteristics of these alloys are given in the following sections.

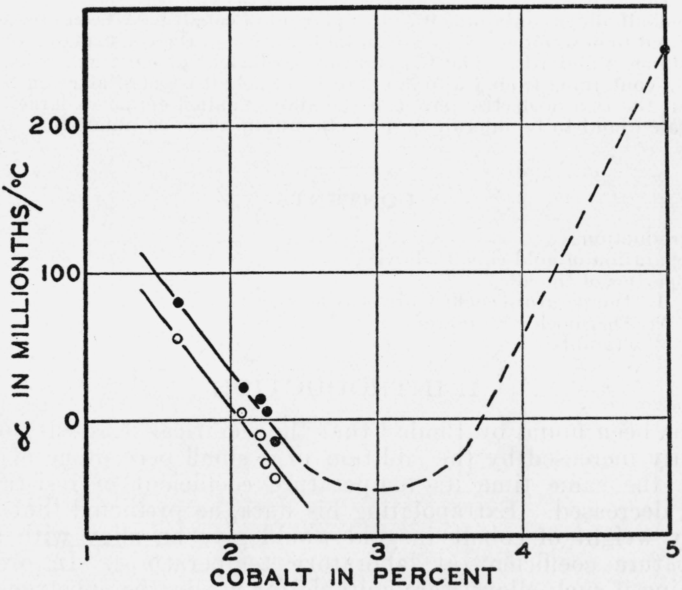

FIGURE 1.—*Temperature coefficients of resistance of gold-cobalt alloys.*

Lower curve is for hard-drawn wire, while upper curve is for wire baked 18 hours at 140° C.

III. PROPERTIES OF THE ALLOYS

1. TEMPERATURE COEFFICIENTS OF RESISTANCE

Ten-ohm coils were constructed of 0.4-mm wire of each of the 7 gold-cobalt alloys. The wire was wound on silk-insulated brass tubes, spaced with silk thread, and the temperature coefficients of resistance were measured. The coils were then shellacked and baked in air at 140° C for 18 hours, after which the temperature coefficients were again measured.

To determine the temperature coefficients, the resistances of the coils were measured at 30 and 40° C. The temperature-resistance curves were not exactly linear, but for the purpose of this investigation it seemed sufficient to determine the temperature coefficient by dividing one-tenth of the change in resistance as the temperature was changed from 40 to 30 ° C by the resistance at 30° C. The temperature coefficient as determined in this way will be designated by α. The curves of figure 1 show how the temperature coefficient depends upon the cobalt content for alloys containing 1.5 to 5 percent of cobalt. The lower curve is for the unbaked coils while the upper curve is for the coils after baking for 18 hours at 140° C.

Figure 1 shows that for coils baked at 140° C for 18 hours a zero value for α is obtained with an alloy containing about 2.2 percent cobalt. A second alloy containing a somewhat larger proportion of cobalt will also have a zero value of α. This was shown by the fact that the alloy containing 5 percent of cobalt had a positive value for α.

The resistivity of the gold-cobalt alloys at about 25° C is shown in figure 2. The fact that there is a considerable scattering of the points

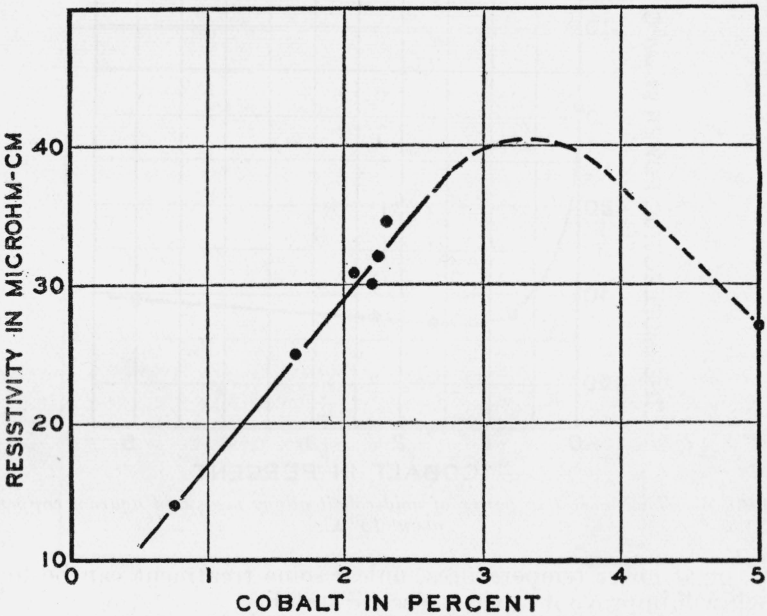

FIGURE 2.—*Resistivity of gold-cobalt alloys at about 25° C.*

would suggest that the components were not perfectly mixed, and that the alloys were therefore not uniform.

2. THERMOELECTRIC POWER

The thermoelectric powers of several of the gold-cobalt alloys against copper were determined by measuring the electromotive force of a couple having one end in an ice bath and the other in an oil bath at about 25° C. The results obtained are shown in figure 3. From this figure it is seen that a maximum (numerically) thermoelectric power against copper of about 47 microvolts per degree centigrade is obtained with about 1 percent by weight of cobalt. With the usual convention [3] the sign of this thermoelectric power is negative. While

[3] Smithsonian Physical Tables, Seventh revised edition. page 317 (1927).

the first 1 percent of cobalt makes a very large change in the thermoelectric power, additional cobalt has comparatively little effect.

The large thermoelectric power of this alloy against copper suggested that it might be used as a thermocouple material. A wire of the 0.75-percent alloy was annealed in air for a short time at 600° C. Measurements of the electromotive force against platinum were made after this annealing, and after two additional heatings in air, each for 7 hours at 350° C. The electromotive force decreased with continued annealing, giving no indication of approaching a steady value. The usefulness of gold-cobalt alloys in thermocouples is therefore probably limited to the measurement of temperatures at or near room tempera-

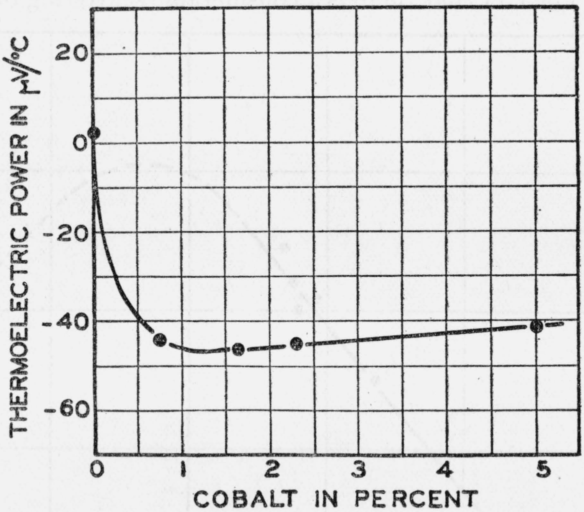

Figure 3.—*Thermoelectric power of gold-cobalt alloys measured against copper, at about 15°* C.

ture, or at lower temperatures, unless some treatment can be found which will improve its thermoelectric stability.

Table 1.—*Data on resistance coils*

Items	Coil no. 1	Coil no. 2
Percentage of cobalt	2.2	2.3
Baking temperature, °C	140	140
Time of baking, hours	48	48
α in millionths/°C	30	−1
Date (1934)	Resistance (in ohms) at 25° C	
	Coil no. 1	Coil no. 2
Oct. 4	9.99733	9.99872
Oct. 6	9.99737	9.99871
Oct. 9	9.99738	9.99867
Oct. 17	9.99735	9.99861
Oct. 26	9.99734	9.99858
Nov. 16	9.99734	9.99857
Dec. 5	9.99733	9.99854

3. STABILITY

The stability of the electrical resistance of two coils of wire made of the gold-cobalt alloys was determined. One of the coils was very satisfactory, while the other decreased in resistance with time, with little indication of approaching a steady value. Table 1 shows the data obtained for these two coils. The values of α given for these coils are larger than those shown in figure 1, as the coils were given additional baking before determining the stability. No explanation can be given of the difference in the performance of these coils. It does not seem that it can be attributed to the difference in the composition of the alloys, and the construction and baking were the same for the two coils.

WASHINGTON, December 18, 1934.