U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

RESEARCH PAPER RP960

Part of Journal of Research of the National Bureau of Standards, Volume 18, January 1937

THERMAL EXPANSION OF CEMENTED TUNGSTEN CARBIDE

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ABSTRACT

This paper gives data on the linear thermal expansion of tungsten carbide-cobalt mixtures containing about 6 and 13 percent of cobalt. These products are called "cemented tungsten carbide" or Carboloy in the United States and Widia in Germany.

The expansion curves of four samples of cemented tungsten carbide are shown in figures 1 and 2. Table 2 gives coefficients of expansion for various temperature ranges between 20 and 400° C. The average coefficient of expansion of cemented tungsten carbide containing 5.9 percent of cobalt, increases from 4.4×10^{-6} for the range between 20 and 60° C to 5.9×10^{-6} for the range between 300 and 400° C. The average coefficients of expansion of the samples of cemented tungsten carbide containing from 12.9 to 13.2 percent of cobalt, increase from 5.0×10^{-6} for the range between 20 and 60° C to 6.7×10^{-6} for the range between 300 and 400° C. For the range from 20 to 400° C, the average coefficients of expansion of the samples of cemented tungsten carbide containing about 13 percent of cobalt are 15 percent greater than the coefficient of expansion of the cemented tungsten carbide containing about 6 percent of cobalt.

Figure 3 shows that the rates of expansion of the samples of cemented tungsten carbide increase linearly with temperature. The rates of expansion of the cemented tungsten carbide containing 13.0 percent of cobalt are greater than the rates for the carbide containing 5.9 percent of cobalt. The rates of expansion of the samples of cemented tungsten carbide are greater than the rates of expansion of tungsten and considerably less than the rates of expansion of cobalt.

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I. INTRODUCTION

Becker [1][1] determined by an X-ray method [2], the coefficients of expansion of two tungsten carbides α–W_2C and WC. He reported the following coefficients of linear expansion: For α–W_2C, a–axis 1.2×10^{-6} and c–axis 11.4×10^{-6} per degree centigrade between 20 and 2,400° C; for WC, a–axis 5.2×10^{-6}, and c–axis 7.3×10^{-6} per degree centigrade between 20 and 1,930° C.

Agte [3] in 1930 reported 5×10^{-6} for the coefficient of linear expansion of a tungsten carbide-cobalt mixture containing 5 percent of

[1] Numbers in brackets refer to references at end of paper.

cobalt, for the range from 20 to 1,000° C. Hidnert [4] in the same year reported coefficients of linear expansion of two samples of tungsten carbide-cobalt mixtures containing about 13 percent of cobalt. The average coefficients of expansion of these two samples increased from 5.0×10^{-6} for the range between 20 and 60° C to 6.0×10^{-6} for the range between 20 and 400° C. The present paper gives additional data on the linear thermal expansion of tungsten carbide-cobalt mixtures containing approximately 6 and 13 percent of cobalt. These mixtures are called "cemented tungsten carbide" or Carboloy in the United States and Widia in Germany.

Data on the thermal expansion of cemented tungsten carbide, which is used in industry, should be available. This material, which belongs to the class of superhard materials, is used extensively in cutting tools. Cemented tungsten carbide has been used for cutting materials such as alloy steels, bronzes, hard rubbers, and fibrous materials. In cutting operations, temperature changes affect the tool and the work. This material, because of its low thermal expansion, undergoes small dimensional change during such operations as cutting and grinding. A knowledge of the thermal expansion of cemented tungsten carbide will be of assistance wherever this alloy may be assembled in instruments constructed of materials having different expansions.

II. MATERIALS INVESTIGATED

Cemented tungsten carbide may be made from an intimate mixture of powdered tungsten carbide (*WC*) and cobalt prepared by ball milling. Hoyt [5] stated that "The mold is constructed to permit electrical heating and is provided with a top and a bottom plunger for applying the pressure. The heating is accomplished either by passing a current through the plungers, using top and bottom electrodes, or by passing current through the mold proper by using side electrodes."

Table 1 gives the dimensions and the cobalt contents of four samples of cemented tungsten carbide, which were investigated. Samples *1374I* and *1375I* were purchased in 1929 from Carboloy Co., Inc., New York, N. Y. Samples *1399I* and *1400I* were furnished to this Bureau, in 1930, by General Electric Co., Schenectady, N. Y.

TABLE 1.—*Dimensions and cobalt contents of samples of cemented tungsten carbide*

Sample	Length	Diameter	Cobalt content
	mm	mm	*Percent*
1374I	7.0	3.8	13.2
1375I	8.7	4.6	13.0
1399I	9.5	6.6	12.9
1400I	9.3	6.8	5.9

III. APPARATUS

On account of the small amounts of cemented tungsten carbide available, the interference method [6] of measuring thermal expansion was employed. At each observation, the temperature was kept constant for a sufficiently long time to make certain that the sample had attained temperature equilibrium.

IV. RESULTS

Since a preliminary test on a sample of cemented tungsten carbide indicated that it oxidized between 430 and 480° C, the expansion tests were not carried above 400° C (approximately). Figures 1 and 2 show the observations that were obtained on heating and cooling. Each expansion curve was plotted from a different origin in order to display the individual characteristics of each curve.

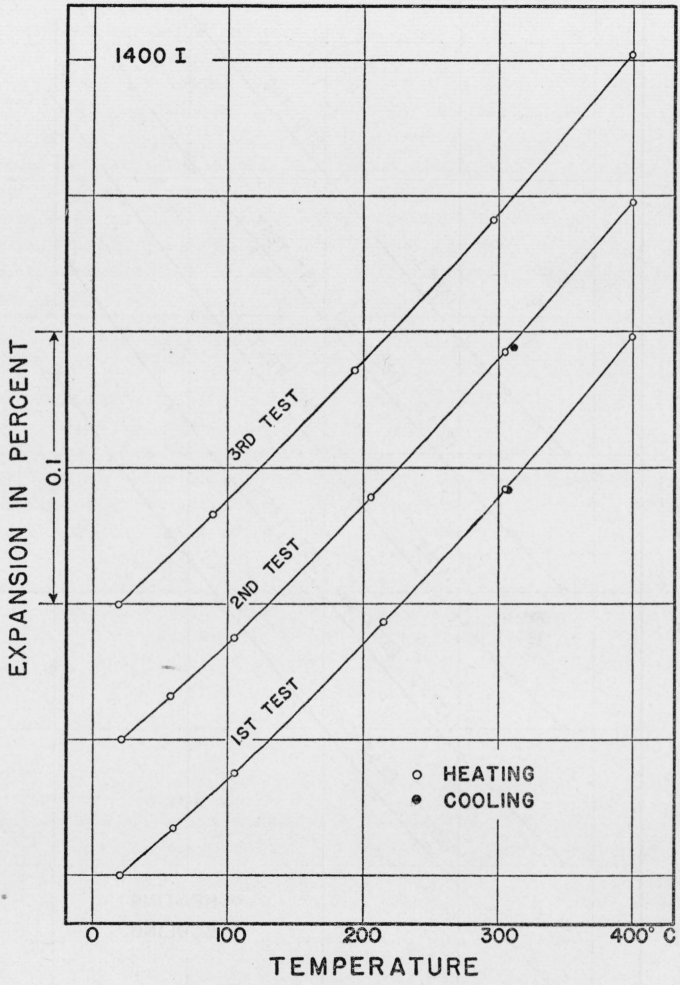

FIGURE 1.—*Linear thermal expansion of sample of cemented tungsten carbide (5.9 percent of cobalt).*

Table 2 gives coefficients of expansion which were obtained from the expansion curves shown in figures 1 and 2. The coefficients of expansion increase with temperature. For the range from 20 to 400° C, the coefficients of expansion of the samples containing about 13 percent of cobalt are 15 percent greater than the coefficient of expansion of the sample containing about 6 percent of cobalt.

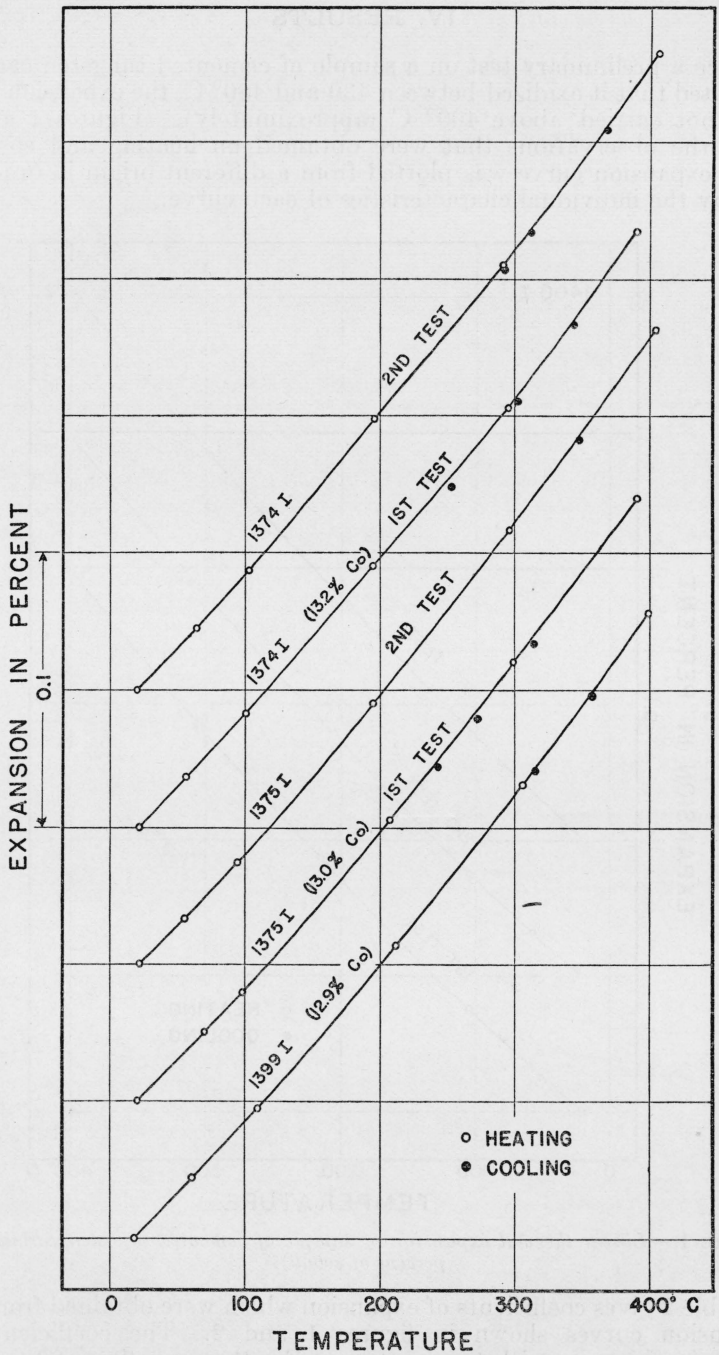

FIGURE 2.—*Linear thermal expansion of three samples of cemented tungsten carbide (12.9 to 13.2 percent of cobalt).*

TABLE 2.—*Average coefficients of linear expansion of cemented tungsten carbide*

Sample	Cobalt content	Test	Average coefficients of expansion per degree centigrade									Change in length after heating and cooling [a]
			20 to 60° C	60 to 100° C	100 to 200° C	200 to 300° C	300 to 400° C	20 to 100° C	20 to 200° C	20 to 300° C	20 to 400° C	
	percent		×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	*Percent*
1400I	5.9	1	4.5	4.5	5.0	5.4	5.9	4.5	4.8	5.0	5.2	+0.05
		2	4.4	4.6	5.1	5.4	5.8	4.4	4.8	5.0	5.2	
		3			5.1	5.4	6.0	4.7	4.9	5.1	5.3	
1399I	12.9	1	5.0	5.2	5.7	6.2	6.7	5.2	5.5	5.7	6.0	+.04
1375I	13.0	1	5.0	5.3	5.7	6.3	6.5	5.2	5.5	5.8	6.0	−.06 [b]
		2	4.9	5.4	5.8	6.3	6.7	5.2	5.5	5.8	6.0	
1374I	13.2	1	5.2	5.4	5.7	5.8	6.8	5.3	5.5	5.6	5.9	+.04 [b]
		2	5.1	5.4	6.0	5.9	6.7	5.2	5.6	5.7	6.0	

[a] The plus (+) sign indicates an increase in length and the minus (−) sign a decrease in length.
[b] Change in length after 2 heating and cooling cycles.

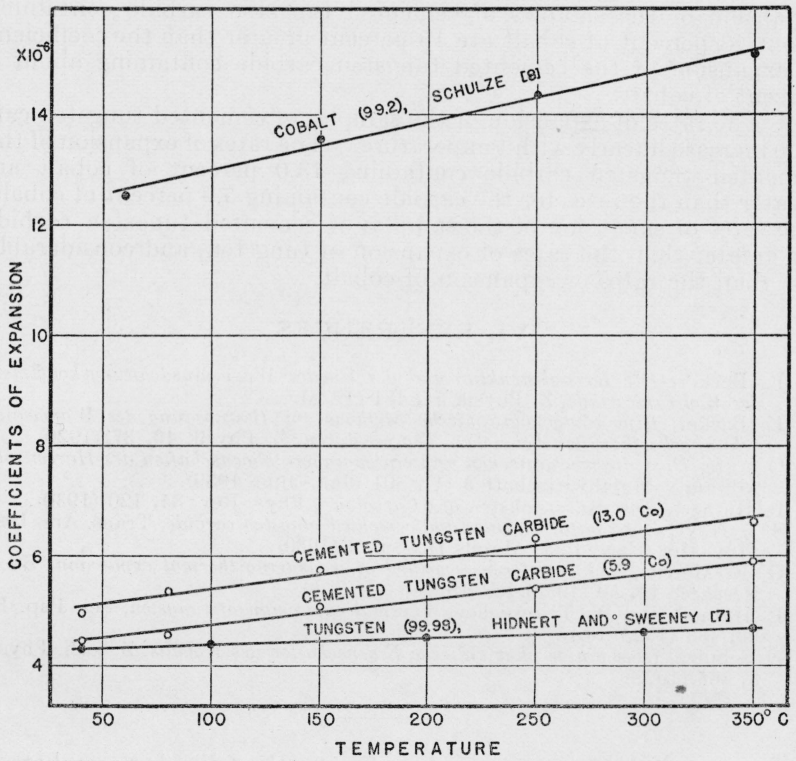

FIGURE 3.—*Comparison of coefficients of expansion or rates of expansion of two samples of cemented tungsten carbide, tungsten, and cobalt.*

Figure 3 shows the coefficients of expansion or rates of expansion of two samples of cemented tungsten carbide containing 5.9 and 13.0 percent of cobalt. Data on tungsten by Hidnert and Sweeney [7] and on cobalt by Schulze [8], are included for comparison. This figure shows that the rates of expansion of the samples of cemented tungsten carbide increase linearly with temperature. The rates of expansion of the cemented tungsten carbide containing 13.0 percent

of cobalt are greater than the rates for the carbide containing 5.9 percent of cobalt. The rates of expansion of the samples of cemented tungsten carbide are greater than the rates of expansion of tungsten, and considerably less than the rates of expansion of cobalt.

V. CONCLUSIONS

1. The average coefficient of expansion of cemented tungsten carbide containing 5.9 percent of cobalt increases from 4.4×10^{-6} for the range between 20 and 60° C to 5.9×10^{-6} for the range between 300 and 400° C.

2. The average coefficients of expansion of the samples of cemented tungsten carbide containing from 12.9 to 13.2 percent of cobalt, increase from 5.0×10^{-6} for the range between 20 and 60° C to 6.7×10^{-6} for the range between 300 and 400° C.

3. For the range from 20° to 400° C, the average coefficients of expansion of the samples of cemented tungsten carbide containing about 13 percent of cobalt are 15 percent greater than the coefficient of expansion of the cemented tungsten carbide containing about 6 percent of cobalt.

4. The rates of expansion of the samples of cemented tungsten carbide increase linearly with temperature. The rates of expansion of the cemented tungsten carbide containing 13.0 percent of cobalt are greater than the rates for the carbide containing 5.9 percent of cobalt. The rates of expansion of the samples of cemented tungsten carbide are greater than the rates of expansion of tungsten, and considerably less than the rates of expansion of cobalt.

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The author expresses his appreciation to the following members of the staff of the National Bureau of Standards: H. W. Bearce, W. Souder and H. S. Rawdon, for valuable suggestions; J. L. Hague for the determinations of the cobalt contents of the samples of cemented tungsten carbide and J. Burks for assistance in the preparation of the figures.

WASHINGTON, October 29, 1936.