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THERMAL EXPANSION OF SOME CHROMIUM-VANADIUM STEELS

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ABSTRACT

Data on the linear thermal expansion of several SAE chromium-vanadium steels have been published previously. The present paper gives the results of an investigation at this Bureau on the linear thermal expansion of two other SAE chromium-vanadium steels (SAE 1625 and 6150) in the annealed condition and in the quenched and tempered condition. These steels were investigated at various temperatures between 20° and 650°C. The coefficients of expansion of the hardened sample tempered at 400°F (204°C) or 800°F (427°C) are less than the coefficients of expansion of the annealed sample. Tempering at 1,200°F (650°C) increased the expansion to that of the annealed sample. For the range from 20° to 650°C, the average coefficients of expansion of all of the samples investigated vary from 13.8×10^{-6} to 14.8×10^{-6} per degree centigrade.

CONTENTS

I. INTRODUCTION

Coefficients of linear thermal expansion of SAE 6115,[1] 6135, and 6140 [1] chromium-vanadium steels, have been determined by Souder and Hidnert [1, 2] [2] and republished in 1939 in the Metals Handbook of the American Society for Metals. The present paper gives the results of an investigation of the linear thermal expansion of other SAE chromium-vanadium steels which are strictly in accordance with SAE specifications.

Chromium-vanadium steels are used for a variety of purposes. Publications by Vanadium Corporation of America [3] and Priestley [4] give information about the mechanical properties and uses of these steels.

II. MATERIALS INVESTIGATED

The chemical composition and the heat treatment of five samples that were investigated are given in table 1. Two of these samples are SAE 6125 chromium-vanadium steels and the other three samples SAE 6150 chromium-vanadium steels.

[1] Chemical composition not strictly in accordance with SAE specification.
[2] The numbers in brackets indicate the references at the end of this paper.

TABLE 1.—*Coefficients of linear expansion of chromium-vanadium steels*

Sample	SAE No.	Chemical composition							Heat treatment	Test	Average coefficients of expansion per °C							Change in length after heating and cooling [a]
		C	Mn	Si	P	S	Cr	V			20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	20° to 650°C	
		%	%	%	%	%	%	%			×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	%
1610 [b]	6125	0.22	0.75	0.27	0.019	0.033	0.96	0.17	Annealed at 1,650° F for 3 hours and furnace cooled.	1	12.2	12.7	13.3	13.7	14.1	14.4	14.6	+0.001
1611 [b]	6125	.22	.75	.27	.019	.033	.96	.17	Heated for ½ hour at 1,475° F, quenched in oil and tempered 4 hours at 400° F.	1	12.0	12.5	12.9	13.0	13.3	13.7	13.8	−.044
										2	12.1	12.6	13.2	13.7	14.1	14.4	14.6	.000
1612 [c]	6150	.53	.80	.15	.015	.020	1.02	.17	Annealed at 1,575° F for 3 hours and furnace cooled.	1	12.4	12.8	13.4	13.9	14.2	14.5	14.7	−.006
1613 [c]	6150	.53	.80	.15	.015	.020	1.02	.17	Heated for ½ hour at 1,575° F, quenched in oil, heated for 3 hours at 800° F and air cooled.	1	11.8	12.4	13.1	13.6	13.9	14.1	14.2	−.042
										2	12.5	12.9	13.5	14.0	14.3	14.7	14.8	+.000
1614 [c]	6150	.53	.80	.15	.015	.020	1.02	.17	Heated for ½ hour at 1,575° F, quenched in oil, heated for 3 hours at 1,200° F and air cooled.	1	12.3	12.7	13.4	13.9	14.3	14.7	14.8	+.002

[a] Determined from the expansion curve on heating and the contraction curve (or observation) on cooling. The plus sign indicates an increase in length, and the minus sign a decrease in length.

[b] Samples 1610 and 1611 from basic open-hearth heat (about 100 tons); forged from 1½-inch diameter rolled bar to ⅝-inch diameter; heat treated as indicated in column marked "Heat treatment;" machined to ⅜-inch diameter by 12⅝ inches long.

[c] Samples 1612, 1613, and 1614 from basic electric-furnace heat (15 tons), which was rolled to 4-inch square billets. The billets were then treated as follows: (a) Chipped and ground; (b) rolled to ⅝-inch rounds; (c) open-annealed at 1,380° F (½ hour); (d) cold-drawn 0.580 inch round; (e) pack annealed at 1,350° F (6 hours), cooling with furnace to 1,200° F, and then air cooled in container—total time 34 hours; (f) heat treated as indicated in column marked "Heat treatment"; and (g) machined to ⅜-inch diameter by 12⅝ inches long.

III. APPARATUS

The samples were investigated at various temperatures between 20° and 650° C with the precision comparator type of thermal-expansion apparatus described by Souder and Hidnert [5]. The white furnace shown at the left of figure 1 of their publication was used. Figure 5 of the same publication shows the details of mounting the sample in the furnace. The distance between the two sharp V notches on each sample was 300 mm.

Platinum-osmium observation wires (6½ percent osmium) were used. The diameter of each observation wire was 0.050 mm. A vane weighing 18 g was attached at the bottom of each observation wire and suspended in oil to damp out vibrations.

IV. RESULTS

The observations obtained on the linear thermal expansion of the five samples of chromium-vanadium steels at various temperatures between 20° and 650° C are shown in figures 1 and 2. Each expansion curve was plotted from a different origin. Two expansion tests were made on samples 1611 and 1613, for in the first tests the observations on cooling lie appreciably below the expansion curves obtained on heating. Results obtained in a second test represent data on material after the heat treatment incident to the first test.

In each test except the first tests on samples 1611 and 1613, the observations on cooling are very close to the expansion curve. This occurs in each case when the sample had been annealed or if the sample had been heated to 1,200° F (about 650° C) after quenching.

The average coefficients of expansion in table 1, were obtained from the expansion curves of figures 1 and 2. This table also shows the difference in length before and after each expansion test.

A comparison of the coefficients of expansion of samples 1610 and 1611 shows that the expansion of the hardened sample which had been tempered at 400° F (204° C) is less than the expansion of the annealed sample. The tempering produced by the first test to 1,200° F. (650° C) increased the expansion (in the second test) to that of the annealed sample. This effect is also indicated by the contraction curve of the first test and the expansion and contraction curves of the second test.

Similarly, for samples 1612 and 1613, it is evident that the expansion of the hardened sample which had been tempered at 800° F (427° C) is less than the annealed sample. The tempering produced by heating to 1,200° F (650° C) in the first test, also increased the expansion (in the second test) to that of the annealed sample. This effect is also indicated by the contraction curve of the first test and the expansion and contraction curves of the second test.

The tempering at 1,200° F (650° C) for sample 1614 is comparable to the heat treatment incident to the first tests on samples 1611 and 1613 and produced the same expansion as that of the corresponding annealed sample.

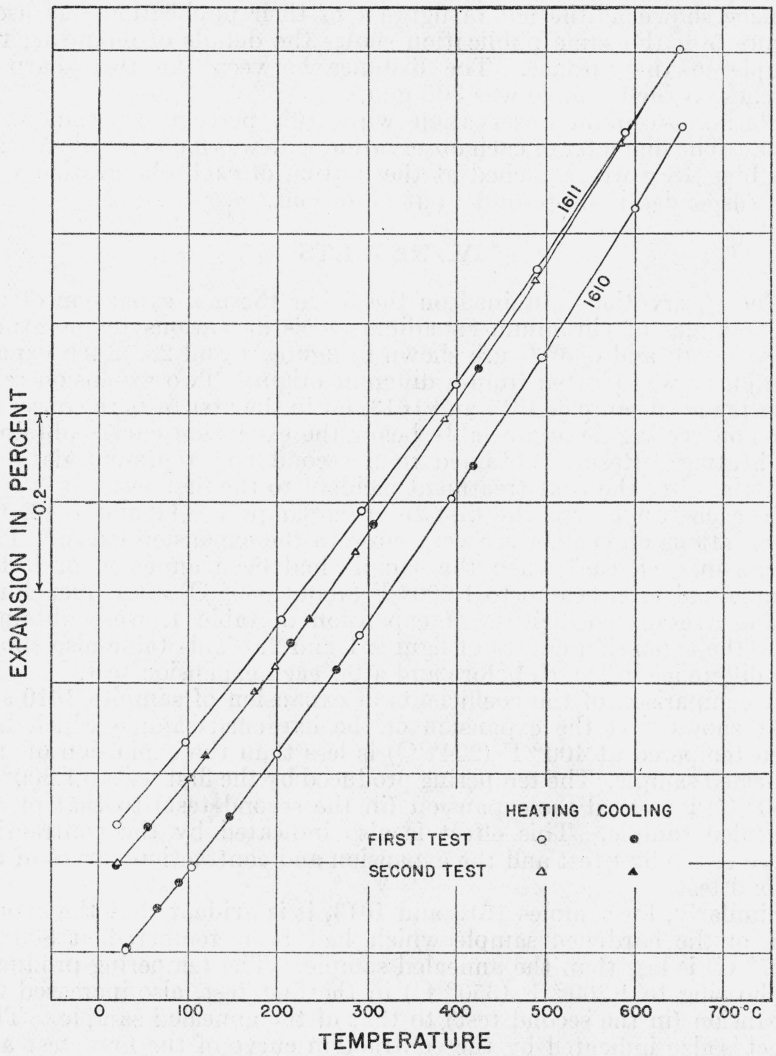

FIGURE 1.—*Linear thermal expansion of two samples of SAE 6125 chromium-vanadium steel.*

C, 0.22; Mn, 0.75; Si, 0.27; P, 0.019; S, 0.033; Cr, 0.96; V, 0.17 percent.
Sample 1610—Annealed at 1,650° F for 3 hours and furnace cooled; sample 1611—heated for ½ hour at 1,475° F, quenched in oil and tempered 4 hours at 400° F.

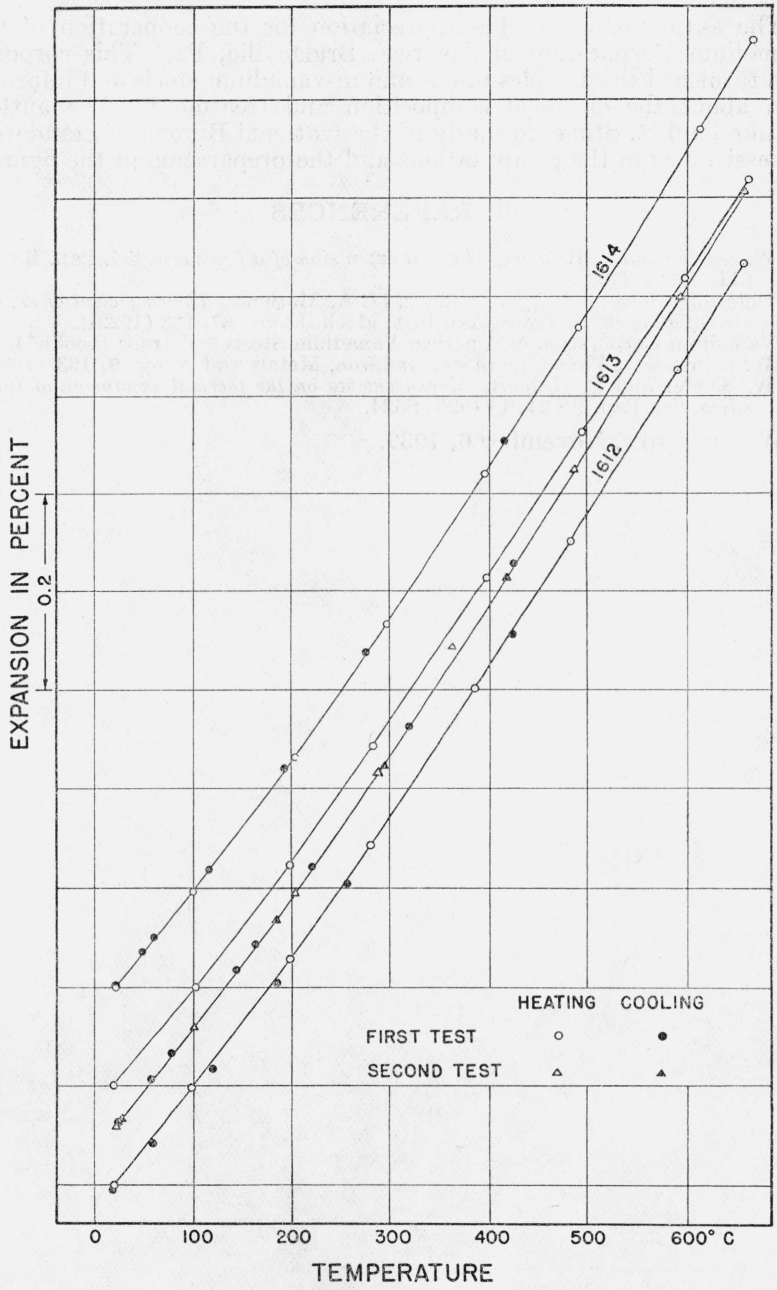

FIGURE 2.—*Linear thermal expansion of three samples of SAE 6150 chromium vanadium steel.*

C, 0.53; Mn, 0.80; Si, 0.15; P, 0.015; S, 0.020; Cr, 1.02; V, 0.17 percent.

Sample 1612—Annealed at 1,575° F for 3 hours and furnace cooled; sample 1613—heated for ½ hour at 1,575° F, quenched in oil, heated for 3 hours at 800° F and air cooled; sample 1614—heated for ½ hour at 1,575° F, quenched in oil, heated for 3 hours at 1,200° F and air cooled.

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V. REFERENCES

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