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O T T A W A October 23, 1945.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1947.

Preliminary Report on Some Physical Properties of Stellite.

(Copy No. 6.)

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Introduction:

This investigation was undertaken at the request of Mr. C. R. Whittemore, Research Metallurgist, Deloro Smelting and Refining Company Limited, Deloro, Ontario. The project at first was concerned entirely with determining the thermal expansion characteristics per se and also to see whether such curves could reveal phase changes which may be occurring. For this work, fourteen bars, representing seven samples (A to G), were received in December, 1944, and the dilatometric measurements were begun.

While this work was being conducted, a request to enlarge the program to include determination of numerous physical properties was received. These Laboratories under-

(Introduction, cont'd) -

took to determine the requested physical properties listed below, and an attempt will be made at the conclusion of the work to shed some light on the metallurgical phases developed in the stellite alloys.

It is intended to supply data on the following physical properties: melting points, thermal conductivity, specific heat, thermal expansion, electrical resistivity, hardness at elevated temperatures, tensile strength at room and high temperature, modulus of rupture, and compressive strength; also, possibly, coefficient of friction. Any additional measurements which may be deemed helpful to the solution of the problem will also be conducted.

The only samples submitted so far are the ones originally intended for determination of thermal expansion coefficients and from which data on hardness, magnetic susceptibility and electrical conductivity have been obtained. The rest of the tests will have to await the arrival of samples from the Deloro Smelting and Refining Co. Limited, as outlined in a letter to them on June 6, 1945.

However, it is thought advisable to report on the work carried out so far and to consider this as an interim report on the project.

Material:

The stellite was supplied in the form of ¼-inch-diameter rods, 4¼ inches long, with ground surfaces. The samples were supplied in pairs, coded as follows:

(Material, cont'd) -

Sample Mk.	Description of Sample
A	Grade 12
B	" 6
C	" 1
D	" 80
E	" 40
F	" 90 Charge 149. Carbon cast.
G	" 90 " 142. Sand cast.

RESULTS:

(a) Thermal Expansion Determinations.

In Table I are given the data on the thermal expansion coefficients on at least one of each pair of samples of each grade of stellite submitted. Originally it was intended to work on only one sample from each pair because of the extreme accuracy with which these determinations could be carried out. In some cases, however, data on both samples are reported. This is because subsequent results on tests of electrical conductivity and hardness showed large differences between some of the "duplicate" samples, and it was thought worth while to see if the thermal coefficients of expansion also varied between these samples. These values were also found to differ. Subsequent data on other properties were therefore unobtainable on certain samples in the "as received" condition, because what were thought to be truly duplicate bars could not serve for the other measurements requested before the completion of the dilatometer work

TABLE I. - Thermal Expansion Data.*

STELLITE: SAMPLE: MK	AVERAGE COEFFICIENT OF THERMAL EXPANSION, X10^6 in. per in. per degree C.									
	0-100°C.	0-200°C.	0-300°C.	0-400°C.	0-500°C.	0-600°C.	0-700°C.	0-800°C.	0-900°C.	0-1000°C. (by extrapolation)
A	11.5	12.1	12.6	12.9	13.3	13.8	14.3	14.8	15.2	15.6
B	13.5	13.8	14.2	14.5	14.8	15.1	15.7	16.2	16.6	16.9
B'	12.5	12.9	13.4	14.0	14.4	14.8	15.3	15.6	15.8	16.0
C	10.2	10.5	10.8	11.1	11.4	11.9	12.4	12.9	13.3	13.7
C'	11.6	11.8	12.2	12.6	13.0	13.4	13.9	14.3	14.5	14.8
D	9.5	10.2	10.6	10.8	11.0	11.3	11.7	12.2	12.6	12.8
E	9.7	10.1	10.4	10.8	11.1	11.6	12.0	12.4	12.8	13.2
F	9.7	10.0	10.3	10.7	11.0	11.4	11.7	11.9	12.5	12.9
G	10.4	10.8	11.1	11.5	11.9	12.2	12.6	12.9	13.3	13.7

* Note: Heating rates of 4° C. per minute were used on all tests.

Specimens were about 0.002 inch shorter on a 4½-inch length after the dilatometer tests.

(Results, cont'd) -

(b) Electrical Conductivity, Magnetic Susceptibility, Hardness Determinations.

The bars supplied for thermal expansion determinations also served to supply data on electrical conductivity, magnetic susceptibility, and hardness. The data are given below in Table II. Note the large differences between samples supposedly supplied in duplicate for B and C.

TABLE II.

Sample MK	Electrical Conductivity* Before	Electrical Conductivity* After	Magnetic Susceptibility** Before	Magnetic Susceptibility** After	Hardness (Rockwell C) Before	Hardness (Rockwell C) After
A	1.815	1.860	-	2.650	-	54.9
A'	1.846	1.843	3.350	3.318	55.9	55.4
B	1.920	2.011	-	0.302	-	60.1
B'	1.855	-	Mag.	Mag.	46.7	48.0
C	1.714	1.725	Mag.	Mag.	-	49.7
C'	1.767	1.794	0.268	0.289	61.0	59.3
D	1.489	1.515	-	0.155	-	67.8
D'	1.490	1.436	0.143	0.205	68.3	67.4
E	1.534	1.560	-	0.122	66.3	66.0
E'	-	1.509	-	0.373***	-	66.5
F	1.505	1.509	-	0.118	-	66.7
F'	1.505	1.533	0.120	0.188	67.5	68.7
G	1.494	1.503	-	0.127	-	64.6
G'	1.490	1.519	0.117	0.146	63.6	64.5

* Conductivity expressed as percentage of conductivity of copper corrected to 20° C.

** Relative values only are given for bars feebly magnetic. Those recorded as "Mag" were too magnetic for test in the laboratory set-up and were noticeably attracted to the hand magnet.

*** Sample E' reheated many times before magnetic measurement made.

(c) Structure.

Microscopic Examination -

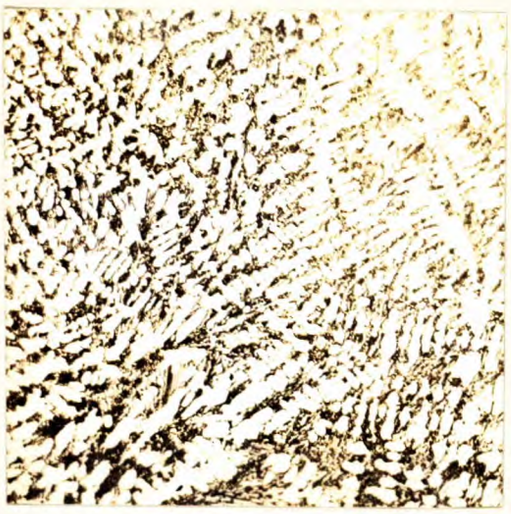
Samples were examined under the microscope before and after the dilatometer tests, to see if any difference in

(Results, cont'd) -

amount or appearance of the phases could be found. In no case could any difference be noted in any one sample before and after heating to the maximum temperature, which was in the neighbourhood of 940° C. Representative microphotographs (X200) are given, Figures 1 to 10, for at least one sample from each pair. In cases where it is thought that duplicates were not supplied, pictures of both samples are included. Murakami's reagent (10 grams $K_3Fe(CN)_6$, 10 grams KOH, 100 ml. water) was used for etching. The correlation of hardness and microstructure is very evident in C and C' but less evident in B and B'. It is apparent that at least some of the carbides exist in the trigonal form.

(Figures 1 to 10 follow,)
(on Pages 7 and 8. Text)
(is resumed on Page 9.)

Figure 1.



SPECIMEN A.

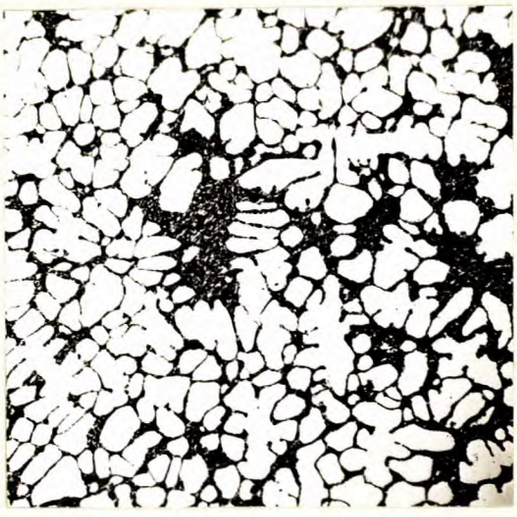
Figure 2.

SPECIMEN A'.

Figure 3.

SPECIMEN B.

Figure 4.

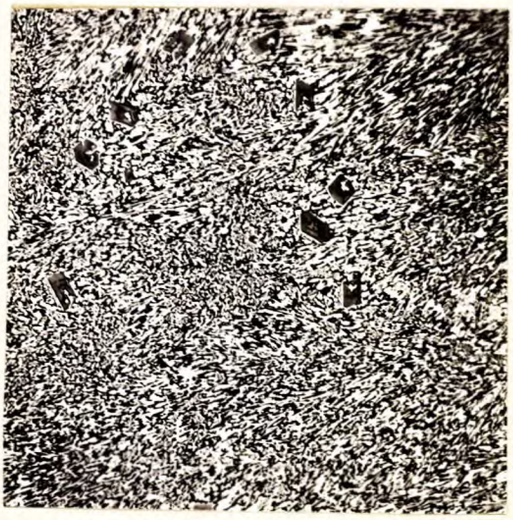


SPECIMEN B'.

Figure 5.

SPECIMEN C.

Figure 6.



SPECIMEN C'.

MICROSTRUCTURE OF STELLITE.
(All of above are at X200 magnification and were etched in Murakami's solution.)

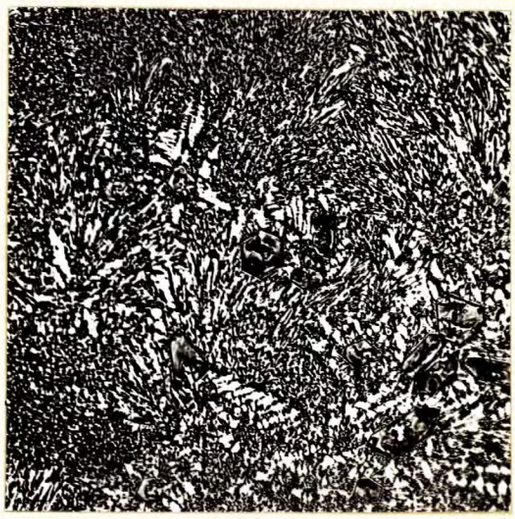
(Results, Structure, cont'd) -

Figure 7.

SPECIMEN D.

-

Figure 8.



SPECIMEN E.

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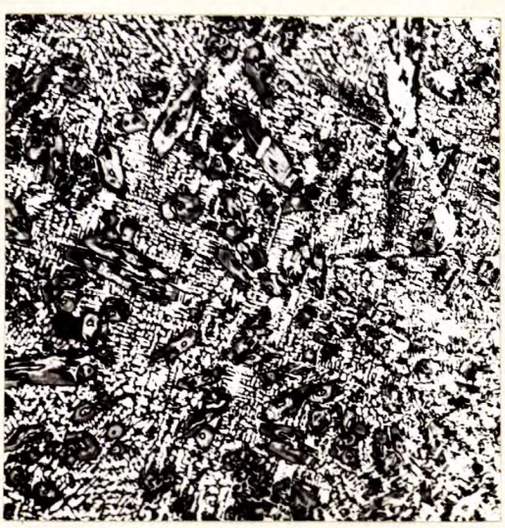
Figure 9.



SPECIMEN F.

-

Figure 10.

SPECIMEN G.

-

MICROSTRUCTURE OF STELLITE.

(All of the above are at X200 magnification and were etched in Murakami's solution.)

(Results, cont'd) -

(c) Structure, cont'd -

X-Ray Diffraction Studies -

The films taken on the metal samples showed only the face-centred cubic pattern of the modified cobalt lattice. It is to be concluded that the matrix consists of only a face-centred cubic material in which solution of the other major elements has occurred.

X-ray diffraction patterns of the carbides obtained by electrolytic removal of the matrix have not resulted in satisfactory patterns for determination of the carbide structure.

(d) Comments.

Both Tables I and II and the microphotographs indicate that the bars supplied as MK "B" and MK "C" were not supplied in duplicate, as shown by the wide divergence of results between the pairs. If this divergence is common for samples taken from the same grade, then it seems that data on physical properties determined from one or two samples must not be regarded as necessarily representative of that grade. However, the close agreement of the data for pairs of Samples D, E, F and G in the "as received" condition would seem to indicate that sampling error is not large and that the difference between the B and C pairs is probably due to some mix-up of samples. Whereas magnetic and hardness readings suggest that B and C should change partners, the thermal expansion and electrical conductivity measurements rule out this possibility.

SUMMARY:

Determinations of the coefficients of expansion of nine stellite samples have been completed. The coefficients

(Summary, cont'd) -

covered quite a wide range of values, no doubt being in large measure characteristic of the compositions employed. Plots of the dilatometric data have not brought out any phase changes in heating from room temperature to about 940° C. This fact was substantiated by microscopic examination before and after heat treatment. However, thermal analysis may reveal why heating of some samples seems to increase hardness and soften others.

All samples heated in the dilatometer and cooled again to room temperature showed a permanent decrease in length of about 0.002 inch in a 4½-inch length. This was probably due to stress relief and this may also account for the general increase in electrical conductivity and magnetic susceptibility.

X-ray diffraction studies show the matrix to give a face-centered cubic pattern, indicating that the other metallic constituents are in solid solution in the cobalt lattice. Attempts to determine the form of the carbide by X-ray diffraction have not given satisfactory results, although by microscopic examination it is apparent that at least part of the carbides exist in the trigonal form.

It is premature to draw any theoretical conclusions from the small amount of data which has been collected so far. When samples are supplied for carrying out the rest of the program, additional information will be made available.

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