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OTTAWA June 27, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1897.

Bismuth in Molybdic Oxide: Its Effect
in Steel Making.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin of Material and Object of Investigation:

For some time the Wartime Metals Corporation has been operating the La Corne Molybdenum Project at Val d'Or, Quebec, sending the concentrates to the Climax Molybdenum Company for roasting in the U.S.A. The La Corne molybdenum concentrates contain considerable bismuth. This was not of great consequence as long as they were being mixed with the Climax production but it might have considerable bearing if the product had to be used undiluted. Accordingly, the Metals Controller's Office at Ottawa asked that tests be conducted to determine the effect the high bismuth in molybdic oxide

(Origin of Material and Object of Investigation, cont'd) -

would have on the steel-making operation.

Materials Used:

Three different molybdic oxides were used. The first, Oxide A, was a sample of La Corne untreated concentrate roasted, containing 1.92 per cent bismuth and 91.1 per cent molybdic oxide. In the second, Oxide B, the bismuth of the molybdenum concentrate had been reduced by ore dressing methods to give a composition of 0.11 per cent bismuth and 92.9 per cent molybdic oxide in the roasted product. The third, C, was C.P. molybdic oxide.

Steel Making and Forming:

All steels were made in a high-frequency Ajax-Northrup 50-pound-capacity furnace. Scrap used was remelted boiler punchers cast into ingot form. Molybdic oxide and nickel were added with scrap. Carbon was added as wash metal as soon as the melting was complete. Chromium, manganese and silicon were added as ferro alloys, in that order, at the end of the heat. A final addition of aluminium equivalent to 12 ounces to the ton was made. Time from start to pour was 30 minutes. Pouring temperature, as measured by a tungsten-graphite thermocouple, was 2,950° F. As far as possible all conditions were held constant for the three heats, each made using molybdic oxide of varying bismuth content.

The steel was poured into a 50-pound Gathman-designed cast iron mould. The ingot was slowly cooled and then subsequently heated in a gas-fired furnace to 2200° F. The ingot, which was about 4½ inches in section at the top, was forged to a 1¼-inch-square bar, forging being conducted at between 2000 and 2200° F. The forged steel was furnace-cooled. Only the middle third of the ingot was used in the

(Steel Making and Forming, cont'd) -

test work.

Chemical Analyses:

Drillings taken from the bars were found to have the following compositions. The steels are designated A, B and C, being, respectively, those made using high-bismuth, low-bismuch and bismuth-free molybdic oxide.

Steel	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Chromium	Nickel	Molybdenum
			- P e r	C e n t	-			
A	0.38	0.75	0.35	0.013	0.022	0.76	1.98	0.44
B	0.38	0.75	0.35	0.013	0.016	0.76	1.98	0.45
C	0.32	0.74	0.33	0.015	0.014	0.90	1.94	0.54

A spectrographic analysis showed a faint trace of bismuth in steel A, and no bismuth in steels B and C. This is for steels that had respectively 0.018 per cent, 0.001 per cent and nil bismuth added to the charge.

Heat Treatment and Preparation of Test Specimens:

All steels were held at 1600° F. for 2 hours and cooled in air. Standard tensile and impact test specimens were then machined from each steel to slightly greater than specified dimensions. These and additional unmachined bars from each steel were held at 1525° F. for 1 hour in a Vapocarb furnace and quenched in 90° F. Houghton's No. 2 quenching oil. The machined samples were then drawn immediately at 650° F. for 1 hour. The unmachined bars were drawn immediately at 1150° F. All material was water-quenched from the draw. The harder test specimens were then ground to size. Similar test specimens were machined from the soft bar.

Mechanical Properties:

Hardness tests made, using a 10-mm. ball loaded with 3,000 kilograms for 30 seconds, showed that steels A and B, drawn at 650° F., had a Brinell hardness of 461; C, steel

(Mechanical Properties, cont'd) -

drawn at 650° F., was 444 Brinell; and the Brinell hardnesses of the steels drawn at 1150° F. were all 302.

Results of mechanical tests are given in the following table:

Tensile Tests.

Steel	Draw temperature, °F.	Ultimate stress, p.s.i.	0.2 per cent proof stress, p.s.i.	Elongation, per cent	Reduction in area, per cent
A	650	228,700	160,000	11.5	40.0
B	650	225,000	159,200	11.5	42.5
C	650	211,250	153,600	13.0	46.0
A	1150	142,500	127,000	20.0	55.5
B	1150	141,900	126,500	22.0	60.0
C	1150	143,700	126,500	18.0	55.0

Impact Tests.

Steel	Test temperature °F.	Steels drawn at 650° F.	Steels drawn at 1150° F.
		- (Foot-pounds) -	
A	70	14	50
B	70	14	50
C	70	14	55
A	0	12	45
B	0	13	44
C	0	11	49
A	-25	12	45
B	-25	13	44
C	-25	10	46
A	-40	13	47
B	-40	14	46
C	-40	11	51

All the above values are the average of at least three readings.

Microscopic Examination:

Samples were cut from all steels, both before and after heat treatment. Metallographic examination showed that all three steels were clean. The 'as forged' structures were typical for this type of steel. The heat-treated specimens showed the expected drawn martensite structures. Structures revealed by a 2 per cent nital etch after polishing are shown

(Microscopic Examination, cont'd) -

in Figures 1 to 7 inclusive. Only one drawn at 1150° F. structure is shown, as all are similar.

Summary:

Chemical analysis, mechanical testing and microscopic examination revealed no significant differences in nickel-chromium-molybdenum steels (S.A.E. 4340 approximately) made in an induction furnace, using molybdic oxides of varying bismuth content. It had been held that for an engineering type steel, even if all bismuth present in the oxide entered the steel it would not be present in sufficient amount to have a deleterious effect. The results of the chemical analyses would show that under induction melting conditions very little bismuth enters the steel, the greater part apparently volatilizing. Certainly, the conclusion would be that bismuth contents, at least up to 2 per cent, can be tolerated in molybdic oxide required for use in the manufacture of engineering steels.

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Figure 1.

X100, etched in 2
per cent nital.

STEEL A, AS FORGED.

Figure 2.

X100, etched in 2
per cent nital.

STEEL B, AS FORGED.

Figure 3.

X100, etched in 2
per cent nital.

STEEL C, AS FORGED.

Figure 4.

X1000, etched in 2
per cent nital.

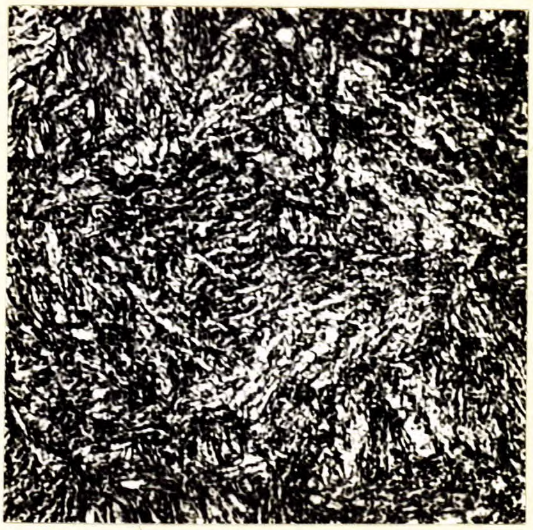
STEEL A, DRAWN AT 650° F.

Figure 5.

X1000, etched in 2
per cent nital.

STEEL B, DRAWN AT 650° F.

Figure 6.



X1000, etched in 2
per cent nital.

STEEL C, DRAWN AT 650° F.

Figure 7.

X1000, etched in 2
per cent nital.

STEEL A, DRAWN AT 1150° F.

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