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CONCENTRATION OF OXIDE MANGANESE ORES FROM LANDER COUNTY, NEV.

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J. P. Hart

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UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
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James Boyd, Director

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INTRODUCTION

As a part of the program of investigation of domestic sources of manganese ore, mining engineers of the Bureau of Mines examined and obtained samples of ore from two properties in the vicinity of Battle Mountain, Lander County, Nev. In addition, samples from three claims in the Carico Lake region, Lander County, Nev., were submitted by private interests. As the ores were too low in grade to be acceptable for the direct production of ferromanganese, their amenability to concentration by ore dressing was investigated.

The Black Rock property is 18 miles south of Valmy, Nev., and is owned by Western Alloys, Inc., Salt Lake City, Utah. The deposit is a replacement of sedimentary rock by manganese oxides. Ore occurs in two main ore bodies designated as the "upper bench" and "lower bench", which could be mined separately. Examining engineers obtained samples from each ore body, and laboratory experiments were made on each sample.

The Black Eagle group of claims is in Lander County, Nev., about 43 miles southwest of Battle Mountain. Ore occurs as a replacement of manganese oxides in shale and chert. The 2-ton sample of ore used for laboratory testing was taken by a Bureau of Mines examining engineer from an adit that partly transversed a 28-foot bed of ore. The property is controlled by Western Alloys, Inc.

The Black Bird, Indian Springs, and Walker (Black Rock) claims are in the vicinity of Carico Lake, about 60 miles south of Battle Mountain and about 45 miles northwesterly of Austin, Nev. The ore bodies are small, elliptical deposits in sedimentary rock. H. E. Chatwin, representing the Golconda Mining Co., Winnemucca, Nev., submitted for testing a sample of ore taken from a 10- by 25-foot open cut on the Black Bird property. William J. Walker, Ely, Nev., lessee of the Indian Springs and Walker claims, submitted samples of ore from each property. The Indian Springs sample was obtained from shallow exploration pits. The Walker sample was taken from the face of a drift on the property.

During the course of laboratory testing, numerous data were collected and tabulated. However, for the sake of brevity, many data of secondary importance have been omitted or condensed. For clarity, the report has been divided into separate sections, each pertaining to the treatment of ore from a single property.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of R. S. Dean, former assistant director of the Bureau of Mines, under whose supervision the manganese program was initiated in 1940, and the valuable suggestions of S. R. Zimmerley, now chief, Metallurgical Division, Region IV. Acknowledgment also is made to H. G. Poole and C. H. Schack for their suggestions and contributions to the organization and prosecution of the work of the Ore Dressing Section. Microscopic work on the ores and many ore-dressing products was done by L. G. Evans and the late R. E. Head. Our appreciation is extended also to H. E. Peterson, chief chemist, and members of the analytical staff for the many analyses of the ores and ore dressing products.

SPECIFICATIONS FOR MANGANESE ORES

At the beginning of the investigation of manganese-ore beneficiation in December 1940, the only product marketable to Metals Reserve Company was ferro-grade manganese grade B, the requirements for which are tabulated below:

Assay, percent					
Mn min.	Fe max.	SiO_2 max.	P max.	Al_2O_3 max.	Zn max.
48.0	7.0	10.0	0.18	6.0	1.0

Later specifications were modified gradually. As of May 15, 1943, manganese products were acceptable if they contained over 35 percent manganese, less than 3 percent zinc, and less than 1 percent phosphorus. Prices were based upon material containing 48 percent manganese, 6.0 percent iron, and 11 percent silica plus alumina. Premiums were paid for manganese content in excess of 48 percent and iron content below 6 percent, penalties being imposed on products containing less than 48 percent manganese, more than 6 percent iron, or more than 11 percent silica plus alumina.

Specifications for marketable manganese further required that 75.0 percent of the product be coarser than 20 mesh. Therefore, fine material such as table and flotation concentrates must be nodulized or sintered. Sintering further concentrates the manganese owing to the loss of oxygen and other constituents during heat treatment. The impurities, such as silica, iron, alumina, barium, and phosphorus, also are concentrated by sintering. Sintering was done to determine the chemical composition of the final product. The physical nature of the sinter was not studied, as the commercial nodulizing or sintering of manganese concentrates was not included as part of this project.

After the close of World War II, the Metals Reserve Company ceased purchasing manganese ores and concentrates. Therefore, the specifications given here, although correct at the time of the laboratory investigations, are no longer in effect.

PART I. - BLACK ROCK PROPERTY

Nature of the Ores

Physical

The Black Rock ore consisted of massive and tough manganese oxides that replaced one or more members of a series of sedimentary rocks. Chief manganese minerals were psilomelane and pyrolusite, although minor quantities of other manganese oxides were present. However, most of the ore was composed of manganese oxides containing innumerable extremely fine particles of quartz or chert in a remarkably uniform distribution through the manganese oxides. A minor portion of the ore consisted of fairly large manganese oxide areas free of nonmetallic inclusions, and a small amount of chert was present as particles up to 1/2 inch in diameter that were low in manganese.

More red ferruginous clay was found in the "upper bench" ore, but in other respects the two samples were nearly identical.

Chemical

The chemical analyses of the two Black Rock samples are shown in table 1.

TABLE 1. - Chemical analyses

Sample	Assay, percent								
	Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	Ba	CaO
Upper bench.....	22.0	2.7	49.6	54.6	0.12	5.6	Nil	0.24	0.7
Lower bench.....	22.2	1.5	54.8	56.9	.06	2.0	Nil	.24	0.3

Methods of Concentration

Beneficiation of Black Rock ore involved the liberation and rejection of silica. As the ore contained some coarse, relatively barren chert, jigging was tried as a means of rejecting a low-grade tailing at coarse sizes. Tabling, manganese flotation, and silica flotation also were investigated, alone and in combination.

Preliminary testing was done on the "upper bench" ore, and only the more favorable methods of concentration were applied to the "lower bench" sample.

Jigging

Two jigging tests were made on unsized and sized fractions of minus 3-plus 10-mesh ore. A very small amount of 37 percent manganese concentrate was made by jigging sized ore. In neither test was a tailing made that assayed less than 18 percent manganese. Finer grinding was indicated for rejection of a low-grade product, and jigging experiments were terminated.

Tabling

Numerous table tests were run with various modifications of procedure, but best results were obtained by tabling unsized minus 100-mesh ore to produce a concentrate, middling, and tailing. The middling was retabled to make a second concentrate and final middling. Results of tabling "upper-bench" ore are given in table 2 with analyses of sinters made from test products given in table 3. Results of using identical procedure on "lower-bench" ore are summarized in tables 4 and 5.

TABLE 2. - Tabling "upper bench" ore

Product	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	Insol.	
Concentrate 1	3.9	49.2	8.6	8.6
Concentrate 2	14.7	46.1	13.8	30.4
Middling	27.8	21.5	54.6	26.9
Tailing	23.0	7.5	83.8	7.7
Slime	30.6	19.2	53.4	26.4
Calculated head	100.0	22.3	53.7	100.0
Combined concentrates (to sinter 1)	18.6	46.8	12.2	39.0
Combined concentrates and middling (to sinter 2)	46.4	31.6	37.6	65.9

TABLE 3. - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	Zn	P	$SiO_2 + Al_2O_3$
Sinter 1	52.8	-	11.5	-	-	-	-
Sinter 2 (calculated)	35.6	-	-	-	-	-	-
MRC base price marketing specifications	48.0	6.0	-	-	Max. 3.0	Max. 1.0	11.0
MRC minimum marketing specifications	Min. 35.0	-	-	-	Max. 3.0	Max. 1.0	-

TABLE 4. - Tabling "lower bench" ore

Product	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	Insol.	
Concentrate 1 (to sinter 1)	11.5	47.7	11.7	25.2
Concentrate 2	16.8	34.6	34.0	26.8
Middling	15.0	17.9	64.2	12.4
Tailing	29.4	9.6	81.9	13.0
Slime	27.3	18.0	51.4	22.6
Calculated head	100.0	21.7	54.8	100.0
Combined concentrates (to sinter 2)	28.3	39.9	24.9	52.0
Combined concentrates and middling (to sinter 3)	43.3	32.3	38.5	64.4

TABLE 5. - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	Zn	P	SiO_2 + Al_2O_3
Sinter 1........................	53.9	-	11.4	-	-	-	-
Sinter 2 (calculated)..........	44.6	-	-	-	-	-	-
Sinter 3 (calculated)..........	36.2	-	-	-	-	-	-
MRC base-price marketing specifications...............	48.0	6.0	-	-	Max. 3.0	Max. 1.0	11.0
MRC minimum marketing specifications.....................	Min. 35.0	-	-	-	Max. 3.0	Max. 1.0	-

The foregoing data show that only 25 to 39 percent of the manganese in the Black Rock samples was recovered in concentrates that, when sintered, assayed over 48 percent manganese. However, approximately 65 percent of the manganese was recovered in products that probably would sinter to a marketable plus 35 percent grade. Tabling at coarser sizes gave high-grade tailings and low-grade concentrates.

Further elimination of silica was attempted by tabling minus 100-mesh ore, regrinding concentrate and middling through 200-mesh, and retabling. Results were not encouraging, partly owing to the inefficiency of tabling fine material and partly to the large slime loss involved. Only about 20 percent of the manganese was recovered in a high-manganese, low-silica concentrate.

Flotation of Manganese

Several tests were run with aqueous emulsions of fatty acid as collectors for manganese oxides. Best results were obtained by grinding a sample of ore to minus 200-mesh, desliming, and floating deslimed ore with emulsified oleic acid. A recovery of 28 percent of the manganese was made in a concentrate that assayed 40.0 percent manganese and 18.6 percent insoluble. The poor selectivity was probably due to ready flotation of manganese oxide-impregnated gangue. Recovery was limited by the loss of manganese in the slime fraction.

Combined Tabling and Manganese Flotation

A series of tests was run combining tabling and flotation of manganese oxides. Ore was ground to minus 100-mesh and tabled to make a clean tailing, a middling, and a plus 40 percent manganese concentrate. The latter was floated with emulsified oleic acid as collector for manganese oxides. The results were no better than those obtained by simple tabling; 25 percent of the manganese in "upper-bench" ore was recovered in a concentrate that, when sintered, assayed 53.7 percent manganese; 29 percent of the manganese in the "lower-bench" ore was recovered in a product that sintered to 50 percent manganese grade.

Combined Tabling and Silica Flotation

Flotation of silica with cationic reagents was tried as a supplement to tabling in the attempt to raise recovery of manganese in high-grade products. Results showed no improvement over simple tabling; 25 to 30 percent of the manganese was recovered in products that, when sintered, assayed plus 50 percent manganese.

Beneficiation of Slime Fraction

Several tests were run to beneficiate the slime fraction obtained when fine grinding was employed. Flotation of manganese with fatty-acid type collectors showed extremely low manganese-silica selectivity. Flotation of silica with cationic reagent DLT 958 gave better results; 31.8 percent of the manganese in the slime was recovered in a product that assayed 34.9 percent manganese and 24.6 percent insoluble. This product contained approximately 9 percent of the total manganese in the ore and would sinter to plus 35 percent manganese grade. If production of a 35 percent manganese sinter were planned, flotation of silica from slime might be used to advantage in conjunction with tabling.

Conclusions

1. Owing to extremely intimate association of manganese oxides and silica, the Black Rock ores were refractory to concentration by ore dressing.

2. Best results were obtained by simple tabling of minus 100-mesh ore. Only 25 to 39 percent of the manganese was recovered in concentrates that sintered to plus 48 percent manganese. Approximately 65 percent of the manganese was recovered in products that would sinter to plus 35 percent manganese.

3. Attempts to improve recovery of manganese in high-grade products by treatment of table concentrates by retabling, flotation of manganese, and flotation of silica were unsuccessful.

4. Flotation of silica from table slime recovered 31.8 percent of the manganese in the fraction treated in a product that would sinter to plus 35 percent manganese.

PART II. - BLACK EAGLE CLAIMS

Nature of the Ore

Physical

The Black Eagle ore was hard and tough and consisted of manganese oxides, chiefly psilomelane, intimately associated with the siliceous gangue. The ore occurred as two types that graded from one into the other. Type 1 was chiefly chert containing veinlets of manganese oxides that seldom were larger than 200 mesh in width. Type 2 contained numerous fine particles of chert and silica scattered uniformly through a manganese oxide groundmass. These inclusions had an average size of about 200 mesh.

Chemical

The chemical analysis of the Black Eagle ore submitted for testing is shown in table 6.

TABLE 6. - Chemical analysis

Assay, percent							
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Ba	CaO
26.0	1.4	50.6	51.9	0.06	3.5	Tr.	0.3

Methods of Concentration

Intimate association of manganese oxides and silica precluded attempts to beneficiate Black Eagle ore by coarse-gravity methods. Methods of concentration studied in detail were tabling, flotation of manganese, and combined tabling-manganese flotation. Each method will be discussed separately.

Tabling

Several table tests were run in the attempt to reject silica and thus beneficiate the ore. Best results were obtained by the following procedure: A sample of ore was crushed and stage-ground to minus 65-mesh and sized into three fractions: Minus 65- plus 150-mesh, minus 150-mesh sand, and slime. The sand fractions were tabled separately to make a concentrate and tailing. Results are shown in table 7.

TABLE 7. - Tabling

Product	Weight, percent	Assay, percent		Distribution, Mn, percent
		Mn	Insol.	
-65+150-mesh concentrate........	29.2	41.2	28.4	46.5
-150-mesh sand concentrate......	14.0	44.1	21.4	23.9
Slime...........................	13.8	22.6	42.0	12.0
-65+150-mesh tailing............	29.2	9.5	84.1	10.7
-150-mesh sand tailing..........	13.8	13.0	75.0	6.9
Calculated head.................	100.0	25.9	52.0	100.0
Combined concentrate............	43.2	42.1	26.1	70.4
Combined concentrate and slime..	57.0	37.4	30.0	82.4

Tabling sized fractions of minus 65-mesh ore recovered 70.4 percent of the manganese in a high-silica concentrate that assayed 42.1 percent manganese, or recovered 82.4 percent of the manganese at 37.4 percent manganese grade. Sintering would be required for the products to meet size specifications and probably would increase manganese grade to 48.0 and 42.5 percent, respectively.

Tabling of unsized minus 100-mesh ore gave a higher grade concentrate but with lower recovery. About 65 percent of the manganese was recovered in a concentrate that assayed 45.3 percent manganese and 17.6 percent silica.

Production of low-silica concentrates required regrinding of concentrates through 200 mesh and retabling. Only 48.6 percent of the manganese was recovered in a concentrate that assayed 49.7 percent manganese and 10.8 percent insoluble. After sintering, the product assayed 57.1 percent manganese and 8.4 percent silica.

Flotation of Manganese

Flotation tests were run on deslimed and undeslimed ore at various grinds. No low-silica products were made by simple flotation of manganese because of the tendency of manganese oxide-impregnated silica grains to float with manganese oxide particles. However, a good recovery of high-silica manganese concentrate was made by flotation of manganese from minus 65-mesh undeslimed ore using emulsified oleic acid as collector. Results are shown in table 8.

TABLE 8. - Flotation of manganese

	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	Insol	
Cleaner concentrate 1..........	50.2	42.1	25.2	80.4
Cleaner concentrate 2...........	4.3	25.1	54.4	4.1
Cleaner tailing................	9.6	7.3	85.2	2.7
Rougher tailing................	35.9	9.4	79.2	12.8
Calculated head.................	100.0	26.3	51.6	100.0
Calculated rougher concentrate..	64.1	35.7	36.1	87.2

Reagent consumption, pounds per ton: 1.2 pounds sodium silicate, 4.2 pounds oleic acid, 1.0 pound Emulsol X-1.

Over 80 percent of the manganese in the ore was recovered in a concentrate that assayed 42.1 percent manganese and that probably would sinter to 48 percent manganese grade. A recovery of 87.2 percent was obtained in a product that probably would sinter to plus 40 percent manganese. Flotation of deslimed ore gave no better results, as the slight increase in selectivity did not offset the slime loss.

Grade of concentrate was not improved, even when 200-mesh grinding was employed. Although most of the manganese oxides were liberated from the gangue at this size, the ready response to flotation of some of the fine silica limited the grade of concentrate obtained. Repeated cleaning failed to lower insoluble content of flotation concentrate below 22 percent.

Combined Tabling and Manganese Flotation

In an effort to make a high recovery of manganese in a low-silica concentrate, several combined tabling and manganese flotation tests were run. By tabling minus 100-mesh ore and regrinding the table concentrate for further treatment by flotation, only 44 percent of the manganese was recovered in a concentrate that, prior to sintering, assayed 49.5 percent manganese and 11.9 percent insoluble. Tabling minus 100-mesh ore with flotation of combined reground middling, tailing, and slime recovered 81.3 percent of the manganese in a concentrate that assayed 41.7 percent manganese. As this involved method of treatment gave results in no way superior to those obtained by simple flotation concentration, complete details will not be given.

Conclusions

1. The Black Eagle ore was readily amenable to the production of high-silica manganese concentrates, but intimate association of manganese oxides and gangue limited the recovery obtainable in low-silica products.

2. By flotation of manganese oxides, 80.4 and 87.2 percent of the manganese was recovered in products that would sinter to 48 and plus 40 percent manganese, respectively.

3. Tabling-sized fractions of minus 65-mesh ore recovered 70.4 percent of the manganese in a concentrate that would sinter to 48 percent manganese. Inclusion of table slime increased the recovery to 82.4 percent; the combined product would sinter to plus 42 percent manganese.

4. Highest recovery of low-silica manganese concentrate was obtained by tabling minus 100-mesh ore followed by regrinding and retabling the table rougher concentrate. Only 48.6 percent of the manganese was recovered in a concentrate that, when sintered, assayed 57.1 percent manganese and 8.4 percent silica.

PART III. - BLACK BIRD CLAIM

Nature of the Ore

Physical

The Black Bird ore was a highly siliceous, brecciated ore in which psilomelane was the chief manganese mineral and pyrolusite and other manganese oxides were present in minor amounts. The manganese oxides occurred as a cementing material on the surface of quartz and chalcedonic fragments. Although a large proportion of the cementing areas were 20 to 65 mesh in diameter, many of them contained silica inclusions ranging from 65 to 400 mesh. The ore was quite porous and loosely consolidated.

Chemical

The chemical analysis of the Black Bird sample is given in table 9.

TABLE 9. - Chemical analysis

Assay, percent								
Mn	Insol.	SiO_2	Fe	Al_2O_3	P	Zn.	Ba	CaO
12.2	71.9	67.0	4.0	1.4	0.01	Tr.	Nil.	0.7

Methods of Concentration

Rejection of silica was required for the beneficiation of Black Bird ore. In the attempt to remove some barren waste at coarse sizes, jigging was tried. Other treatment methods investigated were tabling, combined tabling and flotation, and simple flotation of manganese. These methods will be discussed under separate headings.

Jigging

A sample of ore was crushed to minus 3-mesh, sized on 6-, 10-, and 20-mesh screens, and the plus 20-mesh fractions were jigged separately. Results were poor; the combined concentrate contained only 27 percent of the manganese at 15.6 percent manganese grade. The combined tail was too high in manganese content (7.9 percent) for rejection. As finer grinding was indicated for liberation, no further jigging tests were made.

Tabling

Best tabling results were obtained by separately tabling sized fractions of minus 48-mesh ore. Middlings from each fraction were reground and tabled with the next successive fraction. Results are shown in table 10.

TABLE 10. - Tabling sized fractions

Product	Weight, percent	Assay, percent Mn	Assay, percent Insol.	Distribution Mn, percent
Combined concentrates..........	16.5	38.2	24.5	51.5
-200-mesh middling and tailing.	28.7	8.4	82.0	19.7
Combined +200-mesh tailing.....	36.2	3.6	80.9	10.7
Slime..........................	18.6	11.9	66.4	18.1
Calculated head................	100.0	12.2	68.5	100.0

Tabling recovered 51.5 percent of the manganese in a concentrate that assayed 38.2 percent manganese and 24.5 percent insoluble. Sintering would be required to meet size specifications and probably would increase manganese grade to about 43.5 percent.

Combined Tabling and Flotation of Manganese

Tabling results showed that nearly 20 percent of the total manganese was contained in the minus 200-mesh middling and tailing product at a grade of 8.4 percent manganese. Therefore, an attempt was made to grade up this product from the foregoing test by flotation. The manganese oxides were floated with an aqueous emulsion of oleic acid stablized with Emulsol X-1 as collector and frother. Results of combined tabling and flotation are summarized in table 11. Analysis of sinter made from combined concentrates is given in table 12.

TABLE 11. - Combined tabling and flotation

Product	Weight, percent	Assay, percent Mn	Assay, percent SiO_2	Distribution Mn, percent
Combined table concentrate........	16.5	38.2	24.5	51.5
Flotation cleaner concentrate....	4.8	30.5	36.6	12.0
Flotation cleaner tailing........	2.1	6.8	84.6	1.1
Flotation rougher tailing........	21.8	3.7	91.8	6.6
+200-mesh table tailing..........	36.2	3.6	80.9	10.7
Slime............................	18.6	11.9	62.4	18.1
Calculated head..................	100.0	12.2	68.5	100.0
Combined concentrates (to sinter)	21.3	36.5	27.2	63.5

Reagent consumption, pounds per ton of ore: 1.2 pounds oleic acid, 0.2 pound Emulsol X-1.

TABLE 12. - Results of sintering

	Assay, percent							
	Mn	Fe	SiO_2	Al_2O_3	P	Zn	CaO	SiO_2+ Al_2O_3
Sinter....................	41.4	3.6	30.4	3.6	0.02	0.6	1.5	34.0
MRC base-price marketing specifications..........	48.0	6.0	-	-	Max. 1.0	Max. 3.0	-	11.0
MRC minimum marketing specifications..........	Min. 35.0	-	-	-	Max. 1.0	Max. 3.0	-	-

By supplementing tabling with flotation of minus 200-mesh middling and tailing, an additional 12 percent of the manganese was recovered at 30.5 percent manganese grade. The combined table and flotation concentrates contained 63.5 percent of the total manganese and, when sintered, assayed over 40 percent manganese.

Flotation of Manganese

Numerous flotation tests were run with emulsified oleic acid as collector for manganese oxide. Best results were obtained by floating sized fractions of ore ground to minus 100-mesh. Approximately 44 percent of the manganese was recovered in a product that, when sintered, would assay plus 40 percent manganese. As simple flotation treatment gave results inferior to those obtained by tabling or combined tabling and flotation, details have been omitted.

Conclusions

1. The low-grade (12.2 percent manganese) Black Bird ore was refractery to beneficiation by ore dressing because of intimate association of manganese oxides and siliceous gangue.

2. By tabling, 51.5 percent of the manganese was recovered in a concentrate that would sinter to approximately 43.5 percent manganese.

3. Scavenging flotation treatment of table middling recovered an additional 12 percent of the manganese at 30.5 percent manganese grade. The combined tabling and flotation concentrates, when sintered, assayed 41.4 percent manganese and contained 63.5 percent of the manganese in the ore.

PART IV. - INDIAN SPRINGS CLAIM

Nature of the Ore

Physical

The principal manganese mineral in the Indian Springs ore was psilomelane, although minor amount of other manganese oxides were identified. The manganese minerals occurred as small fragments uniformly distributed through a colloidal silica and chalcedony gangue.

Chemical

The chemical analysis of the Indian Springs sample on which test work was conducted is given in table 13.

TABLE 13. - Chemical analysis

Assay, percent								
Mn	Fe	SiO_2	Insol.	Al_2O_3	P	Zn	Ba	CaO
19.1	1.9	61.2	62.0	1.0	0.03	0.04	Nil.	1.4

Methods of Concentration

Beneficiation of Indian Springs ore required the liberation and rejection of siliceous gangue. The sample submitted for testing by the owner was small, and therefore the amount of test work was of necessity limited. However, both tabling and manganese flotation was studied in detail and will be discussed under separate headings.

Tabling

A sample of ore was crushed through 20 mesh and screened into four sized fractions. Each fraction was tabled to make a concentrate, middling, and tailing. Results are shown in table 14. Sinter of test products is given in table 15.

TABLE 14. - Tabling sized fractions

Product	Weight, percent	Assay, percent Mn	Insol.	Distribution Mn, percent
Combined concentrate.......	24.8	45.4	19.7	57.8
Combined middling..........	1.9	20.3	57.1	2.0
Combined tailing and slime.	73.3	10.7	76.2	40.2
Calculated head............	100.0	19.5	61.8	100.0
Combined concentrate and middling (to sinter).....	26.7	43.6	22.4	59.8

TABLE 15. - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	Zn	P	$SiO_2+Al_2O_3$
Sinter.................	49.4	2.5	22.3	1.7	Tr.	0.06	24.0
MRC base-price marketing specifications....	48.0	6.0	-	-	Max. 3.0	Max. 1.0	11.0

By tabling, 59.8 percent of the manganese was recovered in a product that, when sintered, assayed 49.4 percent manganese. The reject assayed 10.7 percent manganese, indicating that 20-mesh crushing was insufficient for effective liberation of manganese minerals. Tabling at finer sizes, however, gave no additional recovery because of accompanying increased loss of manganese in slimes.

Flotation of Manganese

Best of a series of manganese flotation tests showed a recovery of 51.8 percent of the manganese in a concentrate that assayed 36.8 percent manganese and 29.0 percent insoluble. When sintered, the product assayed 42.4 percent manganese. The low selectivity was probably due to the nature of the easily floated manganese-silica middling grains, as tabling gave a concentrate lower in insoluble content.

Conclusions

1. Intimate association of manganese oxides with gangue limited the degree to which Indian Springs ore could be beneficiated.

2. Best results were obtained by tabling sized fractions of ore; 59.8 percent of the manganese was recovered in a product that sintered to plus 48 percent manganese.

PART V. - WALKER (BLACK ROCK) CLAIM

Nature of the Ore

Physical

Psilomelane was the chief manganese mineral present in the Walker ore and occurred as minute stringers and veinlets in chalcedony. Microscopic examination indicated that grinding to 65-mesh would be necessary to effect even partial liberation of manganese oxides from gangue.

Chemical

The chemical analysis of the sample of ore submitted from the Walker property is given in table 16.

TABLE 16. - Chemical analysis

Assay, percent								
Mn	Fe	SiO_2	Insol.	Al_2O_3	P	Zn	Ba	CaO
30.6	2.8	35.0	38.0	1.7	0.06	0.04	0.25	1.6

The ore was comparatively high grade and possibly would sinter directly to a marketable plus 35 percent manganese product.

Methods of Concentration

Microscopic examination indicated that relatively fine grinding would be required for even partial liberation of manganese oxides from the siliceous groundmass. Therefore, coarse gravity concentration methods were not tried and only tabling and manganese flotation methods were investigated.

Tabling

A sample of ore was crushed to minus 20-mesh, sized on 48-, 100-, and 200-mesh screens, and deslimed. Each sand fraction was tabled separately to make a concentrate, middling, and tailing. Results are given in table 17, with sinters of test products shown in table 18.

TABLE 17. - Tabling sized fractions

Product	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	Insol.	
Combined concentrate (to sinter 1).................	31.7	47.6	11.4	48.7
Combined middling................	27.3	30.6	38.9	26.9
Slime..........................	13.5	22.8	45.4	9.9
Combined tailing................	27.5	16.3	64.3	14.5
Calculated head.................	100.0	31.0	38.0	100.0
Combined concentrate, middling, and slime (to sinter 2).......	72.5	36.6	28.1	85.5

TABLE 18. - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	Zn	P	$SiO_2+Al_2O_3$
Sinter 1...............	55.0	3.3	11.0	1.2	Nil.	0.09	12.2
Sinter 2...............	42.4	3.0	28.3	1.9	Tr.	.07	30.2
MRC base-price marketing specifications...	48.0	6.0	-	-	Max. 3.0	Max. 1.0	11.0
MRC minimum marketing specifications.......	Min. 35.0	-	-	-	Max. 3.0	Max. 1.0	-

Tabling sized fractions of Walker ore recovered only 48.7 percent of the manganese in a comparatively low-silica concentrate. However, 85.5 percent of the manganese was recovered in a high-silica product that sintered to 42.4 percent manganese grade.

Flotation of Manganese

Numerous flotation tests were run on Walker ore, best results having been obtained by the following procedure: A sample of ore was crushed and ground to minus 65-mesh and deslimed. The deslimed sands were pulped to approximately 25 percent solids in a mechanical subaerated cell. Pulp was adjusted to a pH of 9.1 by the addition of sodium hydroxide, and the manganese oxides were floated with an aqueous emulsion of kerosene and oleic acid stabilized with Emulsol X-30 as collector and frother. The rougher manganese concentrate was cleaned once. Results are given in table 19. Sinter analysis is shown in table 20.

TABLE 19. - Flotation of manganese

Product	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	Insol.	
Concentrate..............	64.2	40.3	25.1	81.4
Cleaner tailing...........	3.7	12.8	72.0	1.5
Rougher tailing...........	15.6	8.2	82.2	4.0
Slime.....................	16.5	25.2	43.0	13.1
Calculated head...........	100.0	31.8	38.7	100.0
Combined concentrate and slime (to sinter).......	80.7	37.2	28.8	94.5

Reagent consumption, pounds per ton: 2.8 pounds sodium hydroxide, 21.0 pounds kerosene, 10.5 pounds oleic acid, and 1.1 pounds Emulsol X-30.

TABLE 20. - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	Zn	P	$SiO_2 + Al_2O_3$
Sinter................	42.2	3.4	27.2	2.2	Tr.	0.10	29.4
MRC base-price marketing specifications...	48.0	6.0	-	-	Max. 3.0	Max. 1.0	11.0
MRC minimum marketing specifications.......	Min. 35.0	-	-	-	Max. 3.0	Max. 1.0	-

Because of the response to flotation of manganese-impregnated gangue, no high-grade concentrate was made by flotation. However, excellent manganese recovery was obtained in a product that sintered to plus 42 percent manganese grade. Reagent consumption was excessive, and, therefore, tabling probably would be the most economic method of treatment.

Conclusions

1. Intimate association of manganese oxides and silica in the Walker (Black Rock) ore limited the recovery of high-grade concentrates obtainable by ore-dressing methods of concentration.

2. Tabling recovered 48.7 percent of the manganese in a concentrate that sintered to 55 percent manganese or recovered 85.5 percent of the manganese in a product that, when sintered, assayed 42.4 percent manganese.

3. By flotation of manganese oxides, 94.5 percent of the manganese was recovered in a product that sintered to 42.2 percent manganese. However, reagent consumption was excessive.

4. The ore possibly would sinter directly to a marketable plus 35 percent manganese product.

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