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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

CANADA

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Ottawa, October 2, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2098.

Sinter Tests on Siderite Ore from Algoma Ore Properties Limited, Helen Mine, Ontario.

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Note:
This report relates essentially to the samples as received. It shall not, nor any correspondence connected therewith, be used in part or in full as publicity or advertising matter for the sale of shares in any promotion.

(Copy No. 12.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
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Shipments:

Two shipments, one of 900 pounds and the other of 540 pounds, were received on December 24, 1945, and May 27, 1946, respectively, from the Algoma Ore Properties Limited, Helen Mine, via Sault Ste. Marie, Ontario. This material consisted of:

Shipment No. 1. -

Standard ore	-	450 pounds
High Sulphur ore	-	50 "
Return Sinter fines	-	200 "
Coke Breeze	-	150 "

Shipment No. 2. -

Lump ore -	-	540 pounds.

Characteristics of the Material:

The standard ore in the first shipment had been selected from sinter plant feed over a period of weeks, so that it would be representative. It consisted of siderite ore in which some silica and pyrite were visible, and it had been crushed to pass 1/4" x 1" slot-mesh.

The coarse ore in the second shipment was taken from the primary crusher discharge (-4" lump ore). It was crushed at the laboratory to pass 3/4" mesh and it was employed in tests to determine the sinterability of coarse material.

The sulphur ore was hand-picked from the mine crusher. It arrived here in lumps, and was crushed to pass 1/4" square mesh.

Return sinter fines was material from the circulating load at the sinter plant. It consisted of partially sintered material which had passed through a 1/2" to 3/4" grizzly.

The coke breeze used as fuel in these tests was selected from, the sinter plant fuel. At the plant it was dried, and crushed to pass 5/16".

In this report "Standard Ore" will mean the ore as received (1/4" x 1"), and "Fine Ore" will mean -4 mesh material that has been crushed to that size in the laboratory. "Coarse Ore" will be larger sizes (3/4" x 1"), crushed and screened in the laboratory.

A portion of the coke was used as received (-5/16"), while the rest was crushed to pass 48 mesh. The 48 mesh will be called "Fine Coke," while the 5/16" size fuel will be referred to as "Standard Coke."

Sampling and Analysis:

A head sample was cut from each of the above lots. Analysis of these samples gave the following results:

(Sampling and Analysis, cont'd) -

Material		Fe	S	SiO_2
Shipment No. 1.			- Per Cent -	
Standard ore	-	35.06	1.47	5.58
High sulphur ore	-	29.90	11.78	6.04
Return sinter fines	-	50.44	0.33	7.51
Coke breeze	-		0.80	9.07
Shipment No. 2.				
Coarse ore	-	36.95	2.15	3.30
Return sinter fines*	-	45.60	1.79	--

* Produced in the laboratory by sintering part of the ore of Shipment No. 2.

A screen test was made to determine the sizing of the Standard ore:

Screen Size		Weight, per cent
+3 mesh	-	15.6
+8 "	-	43.0
+28 "	-	22.6
+200 "	-	10.1
-200 "	-	8.7
		100.0

A screen test of the coarse ore (-3/4") gave the following results:

Screen Size		Weight pounds	Weight per cent
-3/4" + 1/2"	-	86	15.8
-1/2" + 1/4"	-	238	43.9
-1/4" + 8 mesh	-	86	15.8
-8 + 28 "	-	58	10.6
-28 +200 "	-	47	8.6
-200 "	-	29	5.3
			100.0

Purpose of Investigation:

This investigation was undertaken in order to learn if simple changes in the plant at Siderite, Ontario, might produce improved results. The objective as outlined in the Company's request was: (1) Elimination of sulphur to 0.45 per cent; (2) a strong sinter that will not break down to fines; and (3) maximum speed of treatment. The following points were investigated:

(Purpose of Investigation, cont'd) -

1. The effect of coarse and fine coke on sintering.

2. The effect of coarse and fine ore.

3. Different procedures for mixing the charge.

Investigative Procedure:

In each test a charge of ore, return fines, coke and water was mixed together and sintered in a small pot 12" x 13-1/2" x 5". The charge was ignited with a gas flame. Care was taken to perform each one of a group of tests in exactly the same manner, so as to compare the effect of different operating conditions with the various types of charge.

When sintering was complete, the pot was allowed to cool, then dumped into a flat pan. The resulting sinter was screened on 3/4" mesh. Plus 3/4" was called "Sinter Cake," and the undersize was called "Sinter Fines." These products were weighed, and the Primary Fines were sampled for analysis. The sinter cake was passed through a jaw crusher set at 1-3/8" to test the ability of the cake to withstand abuse. The crushed product was screened on 3/4" mesh, and the two parts were weighed, then re-combined and sampled. The percentage of the crushed sinter cake that was plus 3/4" mesh gave a rough idea of the physical strength of each type of sinter.

Two groups of tests were made with coarse ore (3/4"). The purpose of these tests was to determine if coarse ore could be satisfactorily sintered.

Two tests in each of the last groups were made with a novel mixing procedure, while the third test was made with a mix that corresponded to that used at the Algoma Ore Properties plant. The new mixing scheme consisted of the

(Investigative Procedure, cont'd) -

following steps:

1. The constituents of the charge were weighed and placed in a bucket.

2. This charge was screened on 8 mesh.

3. The coarse material was placed in the mixer, water was added, and the machine was started.

4. The fine material from the screening operation was dumped into the mixer on top of the wet coarse ore.

In the standard mix, the charge was placed in the mixer, the machine was started, and the water was added to the mixing charge.

RESULTS FROM TESTS:

The tests were made by groups. Two or more tests comprised each group, and each test within the group had only one variable factor in it. Thus, in Group 1, Test 1H was made with standard ore and standard coke; the other tests in the group were made with the same amount of ore, coke, water and return fines (except Test 3H), and the draft and time of the run were maintained at the same value as for Test 1H. Thus it was possible to compare the behaviour of fine ore and fine coke, used in the other tests, with the behaviour of the standard charge in the first test. Other groups were designed in a similar manner.

The following tables give a picture of the different groups, with the results produced:

(Continued on next page)

(Results from Tests, cont'd) -

Group 1.

These tests were made to determine the effect of an overcharge of coke, and of a high draft on the sinter bed.

Charge:

	Test 1H	Test 2H	Test 3H	Test 4H
Standard ore, lb.	36	36		
Fine ore, "			36	36
Return fines, "	8	8		8
Standard coke, "	1.5		1.5	
Fine coke, "		1.5		1.5
Water, c.c.	660	660	660	660

Conditions:

	For Ignition	For Sintering	For Cooling
Draft, inches	4.4	4.4	
Time, minutes	6	9	3

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake + 3/4", % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
1H	44	38.57	1.27	50.0	42.6	0.77	31.8	51.1	0.09	53.5	92.9
2H	44	38.57	1.27	40.9	43.7	0.74	38.6	51.1	0.10	47.0	92.1
3H	36*	35.06	1.47	19.4	48.4	0.61	55.5	51.5	0.29	57.5	80.2
4H	44	38.57	1.27	27.2	50.0	0.26	47.7	51.0	0.08	57.1	93.7

* No sinter fines included in charge.

While the sulphur in the sinter cake in all these tests is below the specification of 0.45 per cent, fine ore with either size of coke gives a stronger sinter and less sinter fines than when standard ore is used.

(Results from Tests, cont'd) -

Group 2.

Tests made to determine the effect of insufficient coke in the charge.

Charge:

	Test 5H	Test 6H	Test 7H	Test 8H
Standard ore, lb.	36	36		
Fine ore, "			36	36
Return fines, "	8	8	8	8
Standard coke, "	1.0		1.0	
Fine coke, "		1.0		1.0
Water, c.c.	670	670	670	670

Conditions:

	For Ignition	For Sintering	For Cooling
Draft, inches	2.4	2.4	
Time, minutes	3	8-3/4	3

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake +½", % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
5H	44	38.57	1.27	45.4	48.3	0.41	31.8	50.5	Tr.	37.5	99.5
6H	44	38.57	1.27	50.0	45.6	0.60	31.8	50.6	Tr.	46.4	99.0
7H	44	38.57	1.27	38.6	49.4	0.26	38.6	50.5	Nil	42.6	100.0
8H	44	38.57	1.27	32.9	49.8	0.28	44.3	50.4	0.014	41.0	98.9

In this group there is a high elimination of sulphur, due probably to the reduction of the amount of coke added. The ignition time was reduced from 6 minutes in Group 1 to 3 minutes. Fine ore again produces less sinter fines with a slight preference for the use of fine coke. The sinter cake is not as strong as that in Group 1, where more coke was used.

(Results from Tests, cont'd) -

Group 3.

In this Group the quantity of coke was midway between those used in Groups 1 and 2. Tests made with sulphur ore mixed with standard ore. The latter expedient was tried, in order to learn whether the size of coke used had an éffect on sulphur elimination.

Charge:

	Test 9H	Test 10H	Test 11H	Test 12H
Standard ore, lb.	30	30		
Fine ore, "			30	30
Sulphur ore, "	6	6	6	6
Return fines "	8	8	8	8
Standard coke, "	1.25		1.25	
Fine coke, "		1.25		1.25
Water, c.c.	800	800	800	800

Conditions:

	For Ignition	For Sintering	For Cooling
Draft, inches	2.4	4.4	
Time, minutes	3	6½	3

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake +¾, % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
9H	44	37.86	2.68	31.8	47.5	0.77	47.7	51.4	0.077	44.0	97.1
10H	44	37.86	2.68	31.8	45.4	1.15	47.7	51.3	0. 11	44.0	95.9
11H	44	37.86	2.68	20.4	50.1	0.44	56.8	51.3	0.051	44.0	98.1
12H	44	37.86	2.68	20.4	49.7	0.57	56.8	51.6	0. 12	47.0	95.5

Sulphur elimination was good in all tests. Less sinter fines were produced from fine ore than from standard ore. A slightly stronger sinter was obtained from fine ore and fine coke.

(Results from Tests, cont'd) -

Group 4.

Two tests were made with a high sulphur charge, in order to learn whether fine coke or coarse coke evidenced any superiority in the task of eliminating sulphur.

Charge:

	Test 13H	Test 14H
Standard ore, lb.	16	16
Sulphur ore, "	11	11
Return fines "	12	12
Standard coke, "	1.0	
Fine coke, "		1.0
Water, c.c.	1000	1000

Condition:

	For Ignition	For Sintering	For Cooling
Draft, inches	1.5	2.5	
Time, minutes	3	$6\frac{1}{2}$	3

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake +½", % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
13H	39	38.33	4.02	28.2	50.3	0.68	51.2	52.8	0.13	43.7	96.8
14H	39	38.33	4.02	48.7	44.3	2.05	38.4	52.9	0.19	51.6	95.3

The sulphur in the sinter cake was reduced below 0.45 per cent. Fine coke produces a stronger sinter, but also results in a much higher percentage of sinter fines being made.

(Results from Tests, cont'd) -

Group 5.

Three tests were made using coarse ore, to compare the effects of fine coke or standard coke mixed with the charge in a special manner, and standard coke mixed in the usual way. The special mix will be called "McK Mix," and the usual mix will be "Hel Mix," for convenience.

Charge:

	Test 15H	Test 16H	Test 17H
-3/4" ore, lb.	30	30	30
Return fines, lb.	14	14	14
Standard coke, "		2.5	2.5
Fine coke, "	2.5		
Water, c.c.	1300	1300	1300
Mix	McK Mix	McK Mix	Hel Mix

Conditions:

	For Ignition	For Sintering	For Cooling
Draft, inches	2.5	3.5	
Time, minutes	3.0	10.0	2.0

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake +3/4", % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
15H	44	-	2.03	32.4	50.8	1.18	42.0	54.4	0.65	55.4	68.0
16H	44	-	2.03	30.9	49.0	1.33	44.3	54.8	0.59	50.0	70.9
17H	44	-	2.03	34.0	48.7	1.21	39.2	54.5	0.37	37.7	81.8

Either fine or standard coke produces a strong sinter with a low percentage of fines. The special mix, while producing a stronger sinter, does not reduce the sulphur below 0.45 per cent.

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(Results from Tests, cont'd) -

Group 6.

Three tests were made to check results from Group 5. More water was used with the first test, less with the second, and still less with the third, to give the second two tests the advantage of having a lower amount of water. Tests in Group 5 had appeared to show that more water was required with fine coke than with coarse coke. Less draft was used in Group 6, and more time was allowed.

Charge:

	Test 18H	Test 19H	Test 20H
$\frac{3}{8}$" ore, lb.	30	30	30
Return fines, lb.	14	14	14
Standard coke, "		2.5	2.5
Fine coke, "	2.5		
Water, c.c.	1300	1275	1250
Mix	McK Mix	McK Mix	Hel Mix

Conditions:

	For Ignition	For Sintering	For Cooling
Draft, inches	1.5	2. 5	
Time, minutes	3.0	12. 0	3. 0

Results:

TEST	Feed			Sinter Fines			Sinter Cake			Crushed Sinter Cake+$\frac{3}{4}$, % of Sinter Cake	Per cent Sulphur Eliminated from Sinter Cake
	Wt., lb.	Fe, %	S, %	% of Feed	Fe, %	S, %	% of Feed	Fe, %	S, %		
18H	44	-	2.03	29.5	50.1	1.43	46.6	54.7	0.52	47. 6	74.4
19H	44	-	2.03	30.1	48.7	1.43	45.5	54.7	0.49	48. 7	75.9
20H	44	-	2.03	38.6	48.5	1.22	33.4	54.5	0.38	34. 0.	81.3

Note: These tests check the results from the tests in Group 5.

Apparently, less water in the mix of Test 20H produces more sinter fines and makes a weaker sinter cake as reported in Test 17H.

INTERPRETATION OF RESULTS:

General -

From the tests in Group 1, it is evident that a draft higher than that required causes the formation of a high percentage of sinter fines. In Tests 1H and 2H, with coarse ore, there was a strong blast of air through the bed, whereas in Tests 3H and 4H the fine ore cut down the amount of air passing through. A low draft, especially at the time of ignition, is very important, as shown by the lesser amount of sinter fines in the tests where a lower draft was employed.

Test 3H, Group 1, shows no great variation in the iron content of the sinter cake, although the feed to this test was lower in iron. The amount of fuel used (coke plus sulphur) is the major factor affecting the iron and sulphur assays of the sinter cake. This is borne out by an examination of the other tests.

With fine ore, in pot tests, less sinter fines are formed than with coarse ore. This is not considered as an important penalty against the use of coarse ore in a sinter plant. The cross-sectional area of the sinter bed almost completely controls the amount of fines resulting from a sintering operation, due to the unsintered portion of the charge on the edges and at top and bottom. The amount of fines produced would be in a smaller ratio to the weight of the charge with a large, plant-size bed, than with a small pot test.

The same observation holds in comparing sulphur elimination in pot tests. In a plant operation the sulphur in the product is much lower than in tests, as had been observed by other investigators.

(Interpretation of Results, cont'd) -

Individual Groups -

Group 1 -

In this group it is noted that a heavy charge of fuel produces a strong sinter cake, although higher in sulphur. The high percentage of sinter fines in this group probably is attributable to the high draft used at the time of ignition, and to the fact that not enough water was added to the charge.

Group 2 -

Use of a small fuel charge lowers the sulphur content in both fines and cake. The cake is not as strong as that produced in Group 1, where more coke fused the charge to a greater degree. There is a slight inferiority in sulphur elimination with coarse coke in the charge, while fine ore shows a definite superiority in the amount of sinter cake produced.

Group 3 -

Fine coke is slightly inferior to coarse coke in producing sinter low in sulphur. Again the fine ore produces a large amount of sinter cake.

Group 4 -

These tests were made to check the observations on Group 3. It is noted that fine coke produces a stronger sinter cake, though the amount of sinter fines in the test with fine coke is much larger than with coarse coke. Sulphur elimination is slightly in favour of the coarse coke.

Groups 5 and 6 -

The two groups will be considered together.

The sinter made from coarse ore compares favourably with that made from standard ore and fine ore. Tests 17H and 20H, where coarse coke and the conventional method of mixing the charge were employed, show that extremely coarse ore will

(Interpretation of Results, cont'd) -

not make satisfactory sinter under ordinary conditions of operation. However, if the new method of mixing is employed good results may be obtained with either fine coke or coarse coke.

Comparing Group 5 with Group 6, it is noted that the higher draft used in Group 5 made for a larger amount of sinter fines, but the cake was stronger. In Group 6 there was a smaller amount of sinter fines, but the cake broke up more under crushing.

It will be noted, also, that a lower draft is required to sinter the coarse ore in these groups than with the giner ore of the other groups. Apparently a larger amount of fuel is required to sinter coarse ore than fine ore, from the evidence of these tests. Not enough material was available to test the possibility of making good sinter with coarse ore and a smaller fuel charge. The heavy fuel charge probably is responsible, to a certain degree, for the poor sulphur elimination in these groups. However, the coarse size of the ore is also to blame, in all likelihood. As mentioned earlier in this report, it is difficult to predict plant results so far as sulphur elimination is concerned, with pot tests as a basis.

<u>SUMMARY AND CONCLUSIONS:</u>

This work on sintering Helen Mine siderite has given very definite indications that the following may open the way to better plant practice. These points have been checked, using material other than siderite, and the results have always pointed in the same direction.

<u>1</u>. Fine coke is superior to coarse coke in sintering coarse material, although fine coke is slightly inferior in eliminating sulphur.

(Summary and Conclusions, cont'd) -

2. A change in the method of mixing the charge seems to increase the strength of the sinter when treating coarse ore.

With fine coke in the charge, the fuel is evenly distributed throughout the sinter bed, while with coarse coke the fuel is inclined to segregate. Both economy and elimination of sulphur dictate that the minimum of fuel should be used, only sufficient to fuse the sinter bed. If coarse coke is employed, there are "hot spots" in the bed, due to areas of concentration of fuel. These areas of activity cause channeling in the bed and overheating on the grates. If the amount of fuel is cut down to avoid these difficulties, then a large proportion of sinter fines results from areas in the bed which have insufficient fuel.

With fine coke the fuel is more evenly distributed throughout the bed, and points of violent ignition do not occur.

Coarse ore has yielded a stronger sinter in these tests when the charge was mixed in such a manner that each coarse particle became coated with an envelope of fine ore and fine coke. Charges mixed in the conventional manner did not produce as strong a sinter.

It is recommended that these tests should be followed up with pilot plant runs, to see if the conditions outlined here will produce equivalent results under operating conditions.

These preliminary tests should be followed up by pilot plant runs to determine if coarse ore can be successfully sintered using the new method of mixing the charge, and also to determine the correct amount of coke and water necessary to produce a sinter meeting specifications.

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FKMcK:LB:CG.

(Appendices I and II follow, on Pages 16 to 29.)

APPENDIX

Contents:

I. - Correlation of Laboratory Report With Field Report.
II. - Quality Control.
III. - Copy of Field Report.

I. CORRELATION OF LABORATORY REPORT WITH FIELD REPORT

On reading over my field report (attached hereto), I note that at the time of my visit to Algoma Ore Properties it was generally conceded that fine coke and fine ore produced best results in the sinter plant. From the results of these tests, it appears that fine coke is not an essential, and that it may be possible to increase the size of ore going to the sinter plant.

Improvement of physical character of the sinter is indicated if certain changes are made in mixing the charge. The basic feature of the new mix is that the coarser pieces in the charge shall be coated with an envelope of fines. The theory behind this procedure is that, if the coarse particles are coated with a layer of fine ore and coke, then ignition spreads evenly from particle to particle through the bed, while the bed is kept open for the passage of air. The intense ignition of a coarse piece of coke is dampened to a certain extent by the envelope of fines around it, so that its heat is transferred to the sinter bed, not dissipated uselessly.

It may be argued that such a coating of the coarse particles by the fines is incidental to the standard procedure for mixing. This is true only to a limited degree; in the conventional mix, the fines are inclined to pelletize into balls

(Appendix I, cont'd) -

by themselves, while the coarse particles are not coated to anything like the degree they are when such a mix is deliberately encouraged. These observations are the result of study of mixing charges under the two different conditions.

The desired conditions may be obtained in the mixing charge by:

1. Placing the coarse part of the charge in the mixer, wetting this down with water, and adding the fines to the wet coarse ore.

2. Placing the coarse material in the mixer, and adding a slurry of fines and water to the mixing charge.

The first procedure would involve screening out the fines and sending the two portions to the mixer separately. It is not known to what degree this must be carried; it may be that good results could be obtained if the ore were sent to the mixer, wet down, and then mixed with dry coke added to the mixing charge.

The second procedure would allow for wet grinding of all the coke, or of a fraction of it. The discharge from the grinding circuit could be piped directly to the mixer, and the water in it would serve as moisture for the charge. The objection has been made that coke grinding is out of the question because the material is very abrasive. It is noted, however, that present coke handling costs at the plant are around one dollar per ton, and it seems unlikely that grinding would cost more than fifty cents. It should be noted here that I do not consider fine grinding as necessary. A grinding unit set up to break the coke to minus 4 mesh should be satisfactory.

There appears to be a possibility that coarser ore may be sintered effectively after the above mixing procedure.

(Appendix, I, cont'd) -

The extent to which the size of the ore could be increased is dependent upon the increased difficulty of eliminating sulphur from coarse material. There does not appear to be any difficulty in making a strong, completely sintered cake. Pilot plant tests with coarse ore would be required, in order to learn how much sulphur may be driven off when sintering coarse material. The sintering tests on coarse ore, described here, do not offer a fair comparison with the tests using fine ore. The latter were made with sinter plant fines, low in sulphur; as none of this material was available for the tests of Groups 5 and 6, an artificial product had to be made by partially sintering some of the ore in the laboratory. This material was much higher in sulphur than that from the plant.

While I was at the plant, experiments were in progress to find a method for eliminating the formation of a layer of fines on top of the sinter bed. The same tendency was noted in laboratory tests, and was ascribed to the drying out of the bed under the ignition hood. This allowed the fines, containing most of the fuel, to pass down into the bed. This trouble reduced somewhat when the new mix was employed.

Conclusion -

In writing this report I have tried to follow the suggestions of Mr. C. W. Beck, manager of the plant, at the time of my visit, to the effect that he would like to have the reaction of an outsider to these problems. The more obvious possibilities for improvement have been studied by means of small-scale tests, with results set down in this report. To my mind, the greatest good with the least changes will result if the sintering of coarse ore with the mixing method outlined above is successful.

(Appendix, cont'd) -

II. - QUALITY CONTROL.

At the suggestion of Mr. C. S. Parsons, Chief of the Bureau of Mines, a brief study was made of the possibilities of applying Quality Control in the plant.

Quality control is usually employed only in manufacturing plants, but a sintering plant certainly should benefit by such a study. It has been successfully applied at the asbestos mills at Thetford Mines, Quebec.

Such a procedure in itself would solve nothing. The idea behind Quality Control is that once the difficulty in a process is recognised, then a correct solution to the problem is much easier. This should hold true at Siderite, or in any plant where there is a wide fluctuation in the process over a period of time.

A study of the plant by a quality control expert would first delineate the variables in the process, and from this a method for meeting these variables would be arranged. This would take one of two forms:

1. The conditions in the plant would be varied to handle a change in feed or fuel according to information previously received by the operators about the material coming to them.

2. The feed to the plant would be mixed and graded in such a manner that the plant could operate under similar conditions over a long period of time.

The second of these points seems to be the most easily applied at Siderite. Its efficacy has, possibly, already been proven to a certain degree. I note that the

(Appendix, II, cont'd) -

best production on record to date was made while treating stock-piled ore, during April of 1941. It may be that the simple operation of mixing the ore which is incidental to stockpiling, was sufficient to render operation of the sintering machines easy and effective during that period. Perhaps a study of past records would reveal that such a mixing always results in improved results at the plan t.

Grading of the feed to the sinter plant would be possible by selecting different types of ore at the mine or by charging mine ore of different types to the receiving bins, and selecting a suitable mixture from the bins.

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III. - REPORT ON FIELD TRIP TO THE HELEN MINE MICHIPICOTEN AREA, ONTARIO.

by F. K. McKean, Mining Engineer, Bureau of Mines.

Date of Report: Dec. 7, 1945.

This mine is operated by the Algoma Ore Properties Limited, Helen Mine, via Sault Ste. Marie, Ontario. Mr. Carl W. Beck is the manager and Mr. J. McConnell the sinter plant superintendent.

General:

Present mine production comes from a new pit at the east end of the Helen Mine mountain. Ore is hauled in Euclid trucks along a haulage road on the south side of the mountain to an ore pass that formerly took the production from the west orebody, which is not worked out so far as pit ore is concerned. Both of these orebodies are siderite deposits. A shaft is being readied close to the haul road to the east orebody, at a point midway along the hanging wall of the west orebody.

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Ore is dumped into an underground crushing plant, where it is broken to 4". It is carried to surface by a 400' conveyor where it is loaded in tramline cars. An aerial tram, 15,000 feet long, carries it down off the mountain to the sintering plant on the Algoma Central Railroad.

A sink-and-float plant is in the process of construction beside the present tram loading station. This plant will lower the silica content of the mine ore; it should be ready for the next season.

The mine operates the year round, while the sinter plant operates only during the lake shipping season. Mine production is stockpiled beside the sinter plant during the winter months, by simply tipping tram buckets before they reach the usual ore dump at the plant.

For this year the sinter plant will operate later into the winter, probably until January 1st. During the month of December the sinter will be hauled to the Sault by railroad.

The mine produces 3,000 tons per day, resulting in 2,000 tons of finished sinter and a circulating load of 500 tons of returned fines.

<u>Sintering Plant:</u>

<u>Ore</u> -

Mine ore is stored at the plant in a bin with a capacity of 800 long tons. It is screened on 4' x 8' Tyrock screens, 1" square mesh on the upper deck and 1/4" x 1" slot mesh on the lower deck. Plus 1" mesh goes to a Symons crusher, +1/4" -1" goes to a set of rolls, and -1/4" x 1" material is stored in bins. This is the sinter plant feed: discharge from both crushers is returned to the belt feeding the crush-

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ing-screening plant.

Coke -

Coke breeze from Algoma Steel Corporation is used for sinter fuel. As received it carries 15 to 16% moisture; it must be dried before it can be screened. It is dumped from railway cars and carried up by a Johns conveyor from which it is discharged into a rotary kiln on the first floor. When dry (8% moisture) it is picked up again by the conveyor and is taken to a two-deck Dillon screen. The top deck is 1" mesh, the lower 1/4". Plus 1" material is clinker, chips, etc., and it is sent to waste; +1" -1/4" coke goes to small set of rolls; and -1/4" coke goes to a bin, ready for the sinter plant.

Returned Sinter Fines -

Return fines are picked up below the roasting bed, by the dust collectors at various points, and at the points where the sinter discharges from the machines.

The sinter falls onto a coarse grizzly with 3" openings, and fines from this fall on a fine grizzly, originally set at 1/2" but now more like 3/4". This material is returned to a bin.

Mixing the Charge -

There are six bins from which the Dwight-Lloyd charge is made up: four (1,200 tons) for the crushed ore, another for screened coke, and the sixth for returned fines. An operator sends the required material up to the superhoppers according to signals received from that section.

A separate mixing unit is installed above each of the three Dwight-Lloyd machines. Ore and returned sinter are mixed in one superhopper, while coke is placed in a second superhopper, at each unit. By variable speed conveyors ore

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and coke are drawn from each of the bins, dropping them, at the will of the operator, into a pug mill in whatever proportion he desires. The pug mill mixes the charge, and at the same time water is added, enough to bring it to 3% moisture. A handful of the charge, when mixture is correct, will stand alone if it is squeezed in the hand, then will break up if jarred slightly.

Pug mill discharge is spread over the sinter pallets by means of a reciprocating funnel.

Dwight-Lloyd Machines -

Three 5'' x 77' (seven 11-ft. windboxes; pallets, 5' x 2') Dwight-Lloyd machines are installed. The sinter bed is 13" thick, and rate of travel is such that on an average the sintering time is 21 minutes. The charge is ignited under a brock muffle fired by three oil burners. Hot sinter is knocked off the pallets by an eight-inch fall at the discharge end. Air is sucked through the charge bed by a fan driven by a 500 H.P. motor; a suction of 20 inches (water) is maintained, which is cut down to 8" in the first windbox.

Temperature within the sinter bed is from 2500° to 2700° F., and the temperature of ignition is from 1900° to 2100° F.

Sintering Problems:

Both Mr. Beck and Mr. McConnell are extremely interested in improving sinter plant performance. They are not satisfied that optimum results are now being obtained; they feel that experience over years of operation should result in improvements, but if anything, the opposite is true. To show this trend on an exaggerated scale, here are some figures for a good month in 1941, and for a poor month in

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1945, and for a month in 1944.

April, 1941 - Ore from stock pile from winter mining.

Sinter	Tons per Dwight-Lloyd hour	38.0
	Silica content, ore	5.67
	Silica content, sinter	8.34

May, 1944 - Mine Ore.

Sinter	Tons per Dwight-Lloyd hour	33.0
	Silica content, ore	6.30
	Silica content, sinter	9.30

October, 1945 - Mine Ore

Sinter	Tons per Dwight-Lloyd hour	28.6
	Silica content, ore	7.78
	Silica content, sinter	11.94

This dropping off in production rate is almost certainly explained by various conditions which have changed with the passing years. They are:

1. Higher silica content of the ore.
2. A poorer class of labour.
3. The plant is now using coarser coke than formerly.

The silica in the ore will be lower in future, after the sink-float plant is in operation. Labour conditions will improve; this item is probably not very serious anyway. The Helen people are definitely convinced that the size and class of coke affect the operation, though, as will appear later, a change in the type of coke used would be difficult to bring about.

Over and above the interest in finding the reason for this drop in rate of production (which may be only a passing phase, or may not be subject to correction), the Helen people are keen to study possible improvements. Mr. Beck feels that a research program may point the way to a better product and lower costs, even if nothing could be done about production rate.

His ideas as to the lines of investigation which

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are open for study embrace the following:

1. Cheaper and better ignition, (a) by substituting a coke-fired ignition muffle for the present oil-fired unit, and (b) by adding to the top of the charge a material (e.g. pyrite, nitrate) so that the incidence of ignition may be at a lower temperature.

2. Production of a more homogeneous sinter, with less fines resulting from the breaking up of the sinter cake and less unsintered material in the pallet discharge.

3. A study of different methods of placing the charge on the hearth, different ratios of fuel to ore, and different sizing of both fuel and ore.

4. The use of a different type of sintering machine. He points out that considerable success has been achieved with a cylindrical blast type sintering machine, on an experimental basis, in Minnesota. He would like to know what we think of it.

Mr. Beck understands that some of these points are beyond our scope; he is taking up the matter of the coke-burning ignition muffle with Mr. Dunn, and is making a general review of the present plant with Mr. H. E. Rowen of the Dwight-Lloyd Co., who was at the plant during my visit. I assured him that we are anxious to be of service where we can.

I shall now expand on the subjects mentioned above.

Ignition -

Ignition of the Dwight-Lloyd bed is an expensive part of the process. A high consumption of fuel oil is required to maintain the minimum temperature of 1900° F. under the muffle, that is essential to good operation. A test period in the plant, during which the operators were told to keep oil consumption to a minimum, regardless of their estimation of what was required, showed that this approach was a false saving. The returns of unsintered fines were high, and the sinter cake was not of good quality.

Formerly it was noted that an unconsolidated layer of fines, from 1/2" to 1" thick, always was present on top of the sinter bed. It was decided that if a thin sprinkling

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of coke could be placed over the bed before ignition this might disappear, and at the same time a saving in fuel oil in the muffles could be expected. The investigation is now under way at the plant. A half-inch layer of coke is laid on top of the bed by feeding coke out of a long narrow hopper by means of a slowly revolving cylinder beneath it. The feed system is ingenious and effective; the saving in fuel oil has been considerable; the loose material on top of the bed has now about completely disappeared. But fuel oil saved is more than offset by a higher coke consumption, and the quantity of fines returned from the machines is, inexplicably, as great as before.

A sprinkling of pyrite and coke, mixed and placed on the top of the bed, may lower the ignition temperature and the oil consumption. The ignition point of such a mixture would be low; benefit from the fuel value of the sulphur would be obtained, and the iron content would serve to raise the grade of sinter. A coke-nitrate mixture has been tried, inconclusively, as an aid to ignition. This appears to be too expensive and possibly dangerous.

The use of a coke-fired ignition stove should be effective, if the mechanical details be worked out satisfactorily. An advantage of this system would be that a large amount of cheap heat could be generated, without mixing coke ashes with the sinter.

Coke -

The coke breeze from Algoma Steel Corporation is satisfactory as a fuel, though its physical characteristics are unsatisfactory. To dry it, screen it, and crush the oversize is an expensive operation; as received it runs 16% moisture. As fed to the machines it is all -1/4", and 70%

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-10 mesh.

An experiment was tried, for a month, in which the present screening-drying system was avoided. Coke was screened to 5/8" (the finest size it would pass without previous drying) and the +5/8" material was crushed as at present, while the -5/8" coke was sent to the plant feed bin. Results were poor; this was partly responsible for the low production shown in the month of October, 1945.

There is a possibility that another type of fuel would give better metallurgical results. Anthracite fines have been tried satisfactorily. But present fuel is so cheap and from a source so intimate with the company organization that probably only a small fraction of the fuel purchased could possibly come from elsewhere.

The coke-ore ratio depends upon the sulphur content of the latter. Theoretically, at 5.6% sulphur no coke is required, and at zero sulphur 3.5% coke is required. Actual use shows that from 1% to 1.5% more coke than the theoretical is required, and this overcharging must be increased when the coke is coarser in size.

My opinion is that it has been already proven that finer coke produces better results; the question is how to produce a finer coke at least expense.

Ore -

Though the usual feed to the sinter plant is -1/4" x 1" ore, at times larger sizing has been used, as, for example, when the ore is wet and difficult to screen during the early spring. The coarse ore fed to the Dwight-Lloyd results in lower and poorer production during this period.

This difficulty in screening suggests trouble that

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might be encountered if too fine a size were selected as sinter feed. This trend might also result in more fines passing into the wind boxes, and might cause trouble by blinding the sinter bed.

The worst offense to the operation directly attributable to the ore seems to be in the sulphur content of the latter, or rather, to the variation in the sulphur content. The average sulphur content over a year's time would be around 2%; at times this increases to as high as 10% S. When operating on high sulphur ore the machines won't go slow and the coke must be cut. When ore of a different nature comes into the plant it is difficult to readjust conditions. If the sulphur content is low, sintering is rapid and coke consumption is higher. The trend is for the operators to lag behind on all changes, i.e., to waste both time and fuel from the necessity of playing safe, for after all the most important object is to produce the right kind of sinter.

A system of selecting ore at the pit might be applicable, making it possible for the plant operators to be assured that ore of a definite type would be coming from the mine over a specified interval. However, mining methods are such that only a rough selection could be made even though the high sulphur areas of the orebody are fairly well defined. Hand-picking of high sulphur ore would help, though the expense almost precludes the possibility that it could be used.

Conclusion:

The above discussion of sintering problems at Algoma Ore Properties summarizes most of what was talked over by myself with Mr. Beck, Mr. McConnell, and Mr. Rowen.

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I recommend that a series of small-scale pot sintering tests should be made, in order to establish experimentally what has already been more or less proven by looking over past records of the plant operation; that is, to establish the fact that finer sizes of coke and ore would benefit sinter plant operation, and to show more or less what sizing would be best.

Mr. Parsons has already outlined the procedure of these tests; he says that small pot tests are more suitable for the work in hand than would be large runs on our continuous Dwight-Lloyd machine. To my mind the most important thing is to establish the sizing of coke and ore that produce the best sinter. When this is illustrated, experimentally, there should be further discussion with Mr. Beck regarding the change in plant layout that would be required to achieve the desired change in the physical characteristics of the sinter plant feed.

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