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EXPERIMENTAL TESTS ON THE BENEFICIATION OF CANADIAN
IRON ORES

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The Ore Dressing and Metallurgical Laboratories of the Mines Branch, Department of Mines, Ottawa, were first equipped in 1909 for experimental work on Canadian iron ores, and previous to the war a large amount of test work was conducted on the beneficiation of Canadian iron ores from the deposits of Nova Scotia, New Brunswick, Quebec, and Ontario. During the war the laboratories were used almost entirely for work on the war minerals, and since the war for experimental test and research on ores other than iron. The progress made on the beneficiation of iron ores has been closely watched, and the laboratory equipment for this work kept up to date by the purchase of improved apparatus, so that the pre-war work can be supplemented by further investigations when, by prospecting and development work, representative ore is made available for test.

Experimental work on the beneficiation of Canadian iron ores has been conducted on shipments of a few hundred pounds to forty-five tons, from various localities, such as the Bristol Mines, Bristol, Que., the Bathurst mine, Bathurst, N.B., the Wilbur mine, Wilbur, Ont., the Culham mine, Lanark, Ont., Nictaux-Torbrook mine, Torbrook, N.S., Goulais river, Algoma, Ont., Natashkewan river, Lower St. Lawrence, Que., the Bessemer mine, Bessemer, Ont., the Childs mine, Bessemer, Ont., Riviere des Rapids, Saguenay, Que., Groundhog, Algoma, Ont., Levant mine, Lanark, Ont., Kaministikia, Ont., and Clarendon, Ont. Results of these tests have been fully described in the Summary Reports of the Mines Branch.

The following is a brief summary of the more important results of the experimental tests on the majority of the above ores:

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WILBUR MINE ORE - SHIPMENT 10 TONS

Location of property: Lots 3 & 4, Conc. IX, XII, XIII,
Levant Tp., Lanark Co., Ont.

Character of ore: Moderately fine crystalline magnetite,
the gangue consisting for the most part of
quartz, calcite, and chlorite occurring in seams and stringers
throughout the ore. Other gangue minerals present in smaller
amounts are hornblende and muscovite. Both sulphur and phos-
phorus are low.

Results of preliminary These tests showed the magnetite
cobbing tests: fairly free at about 40 mesh and a
60% Fe concentrate with a low tailing
was made at this mesh.

Results of wet mag- Screen analysis of ball mill
netic separation tests: discharge was - on 100 mesh 24%;
on 200 mesh 67%; thru 200 mesh 33%.
Analyses of crude, concentrate, and tailing were:

| | Crude ore | Concentrate | Tailing |
|-------------------|-----------|-------------|----------|
| | per cent | per cent | per cent |
| Iron | 48.5 | 66.10 | 7.2 |
| Insoluble residue | 13.08 | 3.30 | |
| Sulphur | 0.105 | 0.028 | |
| Phosphorus | 0.011 | 0.004 | |
| Lime | 3.00 | 0.30 | |
| Magnesia | 6.40 | 1.40 | |

Ratio of concentration 1 : 1.43
Recovery 95.3%

WILBUR MINE WASTE DUMP - SHIPMENT 5 TONS

Character of ore: Similar structure to run of mine.
Major portion of gangue-granitic gneiss;
calcite and chlorite present in about same proportion as in
run of mine.

Results of wet mag- Screen analysis of ball mill
netic separation tests: discharge was - on 100 mesh 32%;
on 200 mesh 63.5%; thru 200 mesh
36.5%. Analyses of crude, concentrate and tailing were:

| | Crude ore | Concentrate | Tailing |
|-------------------|-----------|-------------|----------|
| | per cent | per cent | per cent |
| Iron | 38.2 | 64.6 | 5.0 |
| Insoluble residue | 22.18 | 6.11 | |
| Sulphur | 0.101 | 0.023 | |
| Phosphorus | 0.011 | 0.006 | |
| Lime | 3.20 | 0.14 | |
| Magnesia | 7.0 | 1.64 | |

Ratio of concentration 1 : 1.8
Recovery 94.5%

General conclusions: A high grade iron concentrate can be made from both the run of mine and the lower grade waste ore at comparatively coarse grinding. The concentrate would have to be sintered, but the resultant product would be very satisfactory for blast furnace use.

ROBERTSVILLE MINE WASTE DUMP - SHIPMENT 5 TONS

Location of property: Lots 3 & 4, Conc. IX, Palmerston Tp., Frontenac Co., Ont.

Character of ore: Fairly coarse crystalline magnetite in a gangue of diorite country rock. Black hornblende and pink calcite with smaller amounts of white quartz is also associated with the magnetite. Sulphur and phosphorus present in small amounts.

Results of wet magnetic separation tests: Analysis of crude, concentrate and tailing:

| | Crude ore per cent | Concentrate per cent | Tailing per cent |
|-------------------|-----------------------|-------------------------|---------------------|
| Iron | 28.00 | 70.5 | 3.6 |
| Insoluble residue | 50.70 | 3.1 | |
| Sulphur | 0.004 | 0.00 | |
| Phosphorus | 0.028 | 0.014 | |
| Lime | 3.30 | 0.00 | |
| Magnesia | 1.90 | 0.06 | |

Ratio of concentration 1: 2.74
Recovery 91.8%

General conclusions: A high grade iron concentrate was made with a high recovery. The concentrate would have to be sintered, but the resultant product would be very satisfactory for blast furnace use.

CULHAM MINE ORE - SHIPMENT 3 TONS

Location of property: N. $\frac{1}{2}$ Lot 21, Conc. VII, Bagot Tp. Renfrew Co., Ont.

Character of ore: Moderately fine-grained crystalline magnetite, the gangue consisting of schistose material, calcite and iron pyrites. Both sulphur and phosphorus are present in objectionable amounts.

Results of wet magnetic separation tests:

Analyses of the crude, concentrate, and tailing were:

| | Crude ore | Concentrate | Tailing ⁶ |
|-------------------|-----------|-------------|----------------------|
| | per cent | per cent | per cent |
| Iron | 47.7 | 67.0 | 6.6 |
| Insoluble residue | 9.3 | 2.5 | |
| Sulphur | 1.65 | 0.357 | |
| Phosphorus | 0.179 | 0.074 | |
| Lime | 4.20 | 0.10 | |
| Magnesia | 0.66 | 0.05 | |

Ratio of concentration 1 : 1.47
Recovery 95.5%

General conclusions: A high grade iron concentrate was made with a high recovery. The phosphorus content is above the bessemer limit, but low enough for mixing purposes. Sintering would be required, and this would reduce the sulphur content and make the resultant product satisfactory for blast furnace use.

BATHURST MINE ORE - SHIPMENTS, 15 AND 10 TONS

Location of property: Lot 12, Range XVII, Bathurst Tp., Gloucester Co., N.B.

Character of ore: A compact cryptocrystalline mixture of hematite, magnetite and quartz. The ore possesses a somewhat laminated structure, although an alternate banding of hematite, magnetite, and quartz is not apparent to the naked eye. Hematite and magnetite appear to be intimately associated in about equal proportions, the colour and streak of the ore varying from red to black, according to the proportion of ferric iron.

Results of wet magnetic separation tests: Analyses of crude, concentrate and tailing were:

| | Crude ore | Concentrate | Tailing |
|-------------------|-----------|-------------|----------|
| | per cent | per cent | per cent |
| Iron | 48.7 | 60.3 | 38.2 |
| Ferrous oxide | 18.1 | 23.8 | 9.6 |
| Ferric oxide | 49.4 | 59.7 | 43.8 |
| Insoluble residue | 16.9 | 7.7 | |
| Sulphur | 0.127 | 0.046 | |
| Phosphorus | 0.760 | 0.350 | |

Ratio of concentration 1 : 2.1
Recovery 58.8%

General conclusions: A good grade of concentrate was produced but with a low recovery of the iron. The loss in iron was due to the hematite in the crude reporting in the tailing. This method of concentration is not adaptable to the Bathurst ore. Magnetic cobbing tests and jig tests were made on the ore carefully sized, but by both these methods, it was found that the grade could not be raised any appreciable extent without a high loss of the iron content. It would seem that concentration methods beyond a rough cobbing to remove any waste material broken with the ore, are not applicable to Bathurst ore.

TORBROOK MINE ORE "HEMATITE VEIN" - SHIPMENT 15 TONS

Location of property: Nictaux Torbrook area, Annapolis Co., N.S.

Character of ore: The Torbrook hematite vein is composed of hard compact ore consisting of the mixed finely crystalline magnetite and hematite of the specular variety. The gangue is predominantly siliceous, although lime and magnesia are present in small amounts. Hematite and magnetite exist in about the proportion of 1 to 2.6 respectively.

Results of wet magnetic separation tests: Analyses of the crude, concentrate, and tailing were:

| | Crude ore per cent | Concentrate per cent | Tailing per cent |
|-------------------|-----------------------|-------------------------|---------------------|
| Iron | 47.2 | 61.0 | 33.0 |
| Ferrous oxide | 14.9 | 21.6 | 9.4 |
| Ferric oxide | 50.8 | 63.7 | 36.7 |
| Insoluble residue | 21.7 | 9.9 | |
| Sulphur | 0.011 | 0.005 | |
| Phosphorus | 1.41 | 0.54 | |
| Magnesia | 0.86 | 0.28 | |

Ratio of concentration 1 : 1.97
Recovery 65.6%

TORBROOK MINE ORE "SHELL VEIN" - SHIPMENT 15 TONS

Character of ore: Very similar in physical characteristics to the "hematite vein" although the former is more magnetic. The ore is siliceous, but contains considerably more lime than the "hematite vein".

Results of wet magnetic separation tests: Analyses of the crude, concentrate, and tailing were:

| | Crude ore per cent | Concentrate per cent | Tailing per cent |
|-------------------|-----------------------|-------------------------|---------------------|
| Iron | 42.5 | 60.5 | 22.8 |
| Ferrous oxide | 19.0 | 21.8 | 8.1 |
| Ferric oxide | 39.6 | 62.1 | 23.6 |
| Insoluble residue | 18.4 | 8.5 | |
| Sulphur | 0.033 | 0.005 | |
| Phosphorus | 1.03 | 0.62 | |
| Lime | 5.50 | 0.58 | |
| Magnesia | 0.37 | trace | |

Ratio of concentration 1 : 1.91
Recovery 74.5%

General conclusions: The Torbrook ores being a mixture of magnetite and hematite, the greater proportion of the hematite is lost in the tailing by fine grinding and magnetic concentration. A concentrate over 60% iron was made in both cases, with low sulphur content but with phosphorus over one-half per cent. Recoveries of 65% to 75% were made depending on the proportion of magnetite to hematite in the ores. Hematite slimes badly and it is, therefore, doubtful if tabling of the tailings from magnetic concentration would pay for the amount recovered by this means.

GOULAIS RIVER ORE - SHIPMENT 15 TONS

Location of property: Tp. 22, Range XII, Algoma District, Ont.

Character of ore: The ore is extremely fine grained. It consists almost entirely of a mixture of silica and magnetite alternating in narrow bands, the two constituents varying widely in their proportions. The leaner bands of quartz contain considerable iron and the richer bands of magnetite appreciable amounts of silica. The average iron content of the shipment was about 35%. Sulphur is low, at about 0.05%.

Result of wet magnetic separation tests:

Analyses of the crude, concentrate and tailing were:

| | Crude ore | Concentrate | Tailing |
|------------------------|-----------|-------------|----------|
| | per cent | per cent | per cent |
| Iron | 33.9 | 50.5 | 4.3 |
| Insoluble residue | 52.1 | 30.9 | |
| Sulphur | 0.056 | traces | |
| Phosphorus | 0.090 | 0.046 | |
| Lime | 0.20 | | |
| Magnesia | 0.10 | | |
| <hr/> | | | |
| Ratio of concentration | 1 : 1.57 | | |
| Recovery | 94.8% | | |

A screen analysis of the concentrate shows 35% on 200 mesh, 65% thru 200 mesh. The -200 mesh concentrate contained 61.4% iron, showing that final grinding to 200 mesh is necessary to produce a product over 60% iron.

General conclusions: From the nature of the ore it would seem that the Babbitt practice of stage crushing, sizing, and cobbing, for the elimination of waste, and final reduction and separation at 200 mesh would be applicable, resulting in a product, on being sintered, better than 60% iron, low sulphur and phosphorus within the Bessemer limits, highly desirable for blast furnace use.

NATASHKWAN SANDS - SHIPMENT 45 TONS

Location of property: Natashkwan River, Lower St. Lawrence, Que.

The shipments made consisted of the samples obtained from an accurate survey and sampling of the deposits. The sands occur at the mouth of the Natashkwan river on the north side of the lower St. Lawrence, for a distance of 6 miles east of the present mouth of the river. The sands consist of rounded particles of titaniferous magnetite and silica sand, washed down by the river and deposited at its mouth. Concentration of the sands has taken place by wave and wind action along the coast.

Results of wet magnetic separation tests:

Average analyses of crude, 1st. and 2nd. concentrates and tailings:

| | Crude per cent | 1st. conc. per cent | 2nd. conc. per cent | Tailing per cent |
|-----------------------------|-------------------|------------------------|------------------------|---------------------|
| Iron | 9.60 | 64.61 | 68.37 | 5.61 |
| Titanic oxide | 2.26 | 2.36 | 1.61 | 2.69 |
| Silica | | 6.35 | 2.27 | 84.58 |
| Sulphur | | | trace | |
| Phosphorus | | | 0.023 | |
| Manganese | | | 0.19 | |
| Lime | | | 0.13 | |
| Magnesia | | | 0.145 | |
| Ratio of 1st. concentration | | 1 : 14.8 | Recovery | 45.5% |
| " " 2nd. | " | 1 : 1.06 | " | 96.0% |
| Final ratio of | " | 1 : 16.2 | Final " | 43.7% |

Note: Iron analysis given above is total iron, and not magnetic iron, hence the low recovery by magnetic separation.

General conclusions: The magnetic iron sands of the lower St. Lawrence can be concentrated up to a high grade iron product, low in sulphur and phosphorus, but containing up to 2% in titanic oxide. The concentrate would require sintering for blast furnace use.

BESSEMER MINE ORE - SHIPMENT 2 TONS

Location of property: Lot 4, Conc. VI, Mayo Tp., Hastings Co., Ont.

Character of ore: Fine grained magnetite, with an associated gangue of calcite, garnet, and epidote and other silicates. The magnetite and gangue are, however, not in a state of intimate mixture, and for this reason it is possible to job out a large proportion of the gangue before final separation.

Result of wet magnetic separation tests: Analyses of crude, concentrate and Tailing were:

| | Crude ore per cent | Concentrate per cent | Tailing per cent |
|-------------------|-----------------------|-------------------------|---------------------|
| Iron | 36.5 | 67.4 | 4.5 |
| Insoluble residue | 35.37 | 5.87 | |
| Sulphur | 0.314 | 0.185 | |
| Phosphorus | 0.026 | 0.007 | |
| Lime | 5.68 | | |
| Magnesia | 0.30 | | |

Ratio of concentration 1 : 1.96
Recovery 94.0%

A screen analysis of the ball mill discharge shows:
 On 100 mesh 22%; on 200 mesh 50%; thru 200 mesh 50%.

General conclusions: The screen analysis shows that very fine grinding is not necessary to produce a high grade concentrate. The concentrate would require sintering, but the resultant product would be high grade, low in sulphur and phosphorus, highly desirable for blast furnace use.

BESSEMER MINE ORE - SHIPMENT 5 TONS

Results of wet magnetic separation, and sintering tests: Analyses of crude concentrate and sinter were:

| | Crude per cent | Concentrate per cent | Sinter per cent |
|------------|-------------------|-------------------------|--------------------|
| Iron | 43.9 | 67.5 | 66.2 |
| Insoluble | 30.88 | 5.98 | |
| Sulphur | 0.3 | 0.11 | 0.023 |
| Phosphorus | 0.028 | 0.019 | 0.016 |

The sinter produced was hard and extremely porous, an ideal product for blast furnace use.

CHILDS MINE - SHIPMENT 2 TONS

Location of property: Lots 11 & 12, Conc. IX, Mayo Tp., Hastings Co., Ont.

Character of ore: Granular magnetite with an associated gangue of calcite, pyroxene, chlorite, etc. Although the ore is comparatively soft, the gangue minerals are so intimately associated with the magnetite, fine grinding is necessary to effect a satisfactory separation of the magnetite from the gangue.

Results of wet magnetic separation tests: Analyses of crude, concentrate, and tailing were:

| | Crude ore per cent | Concentrate per cent | Tailing per cent |
|-------------------|-----------------------|-------------------------|---------------------|
| Iron | 35.0 | 66.4 | 5.7 |
| Insoluble residue | 36.8 | 5.09 | |
| Sulphur | 0.045 | 0.022 | |
| Phosphorus | 0.083 | 0.016 | |
| Lime | 5.83 | | |
| Magnesia | 0.41 | | |

Ratio of concentration 1 : 2
 Recovery 92%

A screen analysis of the ball mill discharge showed: On 100 mesh 33%; on 200 mesh 63%; thru 200 mesh 37%.

General conclusions: The screen analysis shows that very fine grinding is not necessary to produce a high grade concentrate. The concentrate would require sintering but the resultant product would be high grade, very low in sulphur and phosphorus, and very desirable for blast furnace use.

GROUNDHOG ORE - SHIPMENT 15 TONS

Location of property: Groundhog River, Tps. of Keith and Penhorwood, Algoma District, Ont.

Character of ore: Banded structure consisting of bands of magnetite, hematite and jasper, the bands ranging from one-half inch in thickness down to a very small fraction of an inch. The magnetite occurs in some cases in bands almost pure, in others mixed with the jasper band and in other cases finely disseminated through the jasper band. Coarse crushing will not free the thinner bands of magnetite nor the hematite, as the hematite is in most cases firmly attached to the jasper band. The shipment showed an average analysis of 35% iron, 26.5% as magnetite, and 8.5% as hematite with only traces of sulphur, phosphorus and other impurities. The problem was therefore one of raising the metallic iron content and not one of the elimination of impurities.

Results of experimental tests: A large number of tests were conducted including magnetic cobbing, jig and table concentration, and wet magnetic separation tests. Magnetic cobbing tests were made on the sized material from 1" down. These tests showed that an appreciable amount of concentrate could not be recovered in a product approaching 55% metallic iron in the sizes coarser than 1/16". By crushing to 1/16" magnetic cobbing, jig and table concentration of the sized 1/16" tailings a concentrate was produced assaying 53.5% iron, with a recovery of 73.2% and with a ratio of concentration 1:2.

Wet magnetic separation tests on this ore, followed by tabling of the tailings after grinding to 69% through 200 mesh, gave a magnetic product assaying 64% iron, and a hematite product assaying 50% to 55% iron, with a recovery of total iron up to 85%. The ratio of concentration was 1:1.8.

General conclusions: The results of the experimental tests show that a high recovery of the iron content cannot be expected on this class of ore by any simple means of concentration. A fair grade of concentrate was made after grinding to 1/16", and a much better grade on finer grinding. The concentrate would require sintering for blast furnace use. The sinter would be of high silica, low sulphur, and low phosphorus content.

KAMINISTIKWIA ORE - SHIPMENT 240 POUNDS

Location of property: Marks-Wiley property, Loon Lake, Thunder Bay District, Ont.

Character of ore: Banded structure, very similar to Groundhog ore.

Results of experimental tests: Crushing to 4 mesh, jig and table concentration of the sized material gave:

| | | |
|--------------------------|-------------------------|------------|
| Analysis of crude: | Total iron (Fe) | 37.19% |
| | Hematite (Fe_2O_3) | 17.98% |
| | Magnetite (Fe_3O_4) | 33.97% |
| Analysis of conc.: | Iron | 55% |
| Analysis of tails: | Iron | 20% |
| Recovery of iron content | | 70% to 75% |
| Ratio of concentration | | 1 : 2 |

General conclusions: Concentrate too fine for blast furnace use. Would require sintering. Product, high silica, low sulphur, and low phosphorus.

The equipment of the Mines Branch laboratories consists of small and large scale apparatus and machinery permitting of experimental tests on a few hundred pounds, and on carload lots. With the present equipment, a flow sheet duplicating on a small scale the Babbitt practice can be followed, and various combinations can be set up to permit of deviations therefrom. Roasting and sintering tests can be made on a small scale. With very little additional equipment the laboratory investigations could be extended to the point where the details of operation should be worked out in a pilot plant. The chemical laboratories of the Division are equipped for making all necessary determinations in connection with the experimental work, including mechanical determinations of magnetic iron in the Davis testing tube.

The small scale equipment of the laboratories consists of jaw crusher, rolls, pulverizer, screen frame for sizing, jigs, Wilfley table, classifiers, magnetic separators, rotating kiln, roasting furnace, and a Davis magnetic testing machine for the determination of magnetic iron.

The larger scale equipment consists of Blake crusher, picking belt, two sets of rolls, Hardinge ball mill, Traylor ball mill, automatic samplers, two sets of jigs, standard size Wilfley table, Ferraris screen, Hummer screen, Callow duplex screen, Dorr simplex classifier with bowl attachment, launder classifier, Grondal magnetic cobber, Grondal magnetic separator, Davis magnetic log washer, Ullrich magnetic separator, roasting furnaces, duplex Dwight Lloyd sintering pans.

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