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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1775.

Concentration of Iron Ore from the Tomahawk Iron Mines Limited, Lake Township, Hastings County, Ontario.

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Bureau of Mines
Division of Metallic
Minerals
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Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA January 9, 1945.

# REPORT
## of the
## ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1775.

Concentration of Iron Ore from the Tomahawk Iron Mines Limited, Lake Township, Hastings County, Ontario.

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**Shipment:**

A shipment of 5 tons of selected magnetite ore was received on October 5, 1944, from the Tomahawk Iron Mines Limited, Lake township, Hastings county, Ontario, the head office of which is at 67 Yonge Street, Toronto.

**Purpose of Tests:**

This material was sent in to carry out concentration tests to determine the grade of product that could be obtained and to what extent the silica content of the concentrate could be reduced.

Results of Investigation:

Sampling and analysis showed the 5-ton shipment to contain 54.91 per cent iron, 13.00 per cent silica.

By wet magnetic separation, 97.1 per cent of the iron can be recovered, producing a concentrate assaying 71.67 per cent iron, 0.36 per cent silica and 0.65 per cent acid insoluble. This represents a recovery of 74.5 per cent of the weight of ore treated.

The silica content of this concentrate can be reduced to 0.33 per cent by passing it over a Wilfley table, with no appreciable loss in iron.

This table concentrate can be split into two parts. By taking off approximately 37 per cent of it as high grade, a product is obtained assaying 71.67 per cent iron, 0.26 per cent silica, and 0.40 per cent insoluble. The remainder of the table concentrate assays 71.67 per cent iron, 0.37 per cent silica.

The silica in these products can be reduced to 0.22 per cent and 0.34 per cent respectively by re-passing them through the wet magnetic separator, with a loss of approximately 2.6 per cent of the iron.

The results of this investigation indicate that 36.9 per cent of the iron in the feed, or 27.5 per cent of the weight of ore milled, can be recovered as a concentrate assaying 71.76 per cent iron, 0.22 per cent silica and 0.42 per cent insoluble. The remaining 60.1 per cent of the iron, or 47.0 per cent of the weight of feed, is recovered as a concentrate assaying 71.57 per cent iron, 0.34 per cent silica.

As there is no free quartz in the gangue, the per cent of insoluble must be regarded as the important impurity.

Characteristics of the Ore:

Microscopic examination of polished sections shows that the gangue is composed of a medium hard mineral with

(Characteristics of the Ore, cont'd) -

fibrous or columnar structure. Under crossed nicols it shows a light greenish translucence and is regarded as an amphibole, probably tremolite tending toward actinolite.

Metallic mineralization is heavy and is represented almost entirely by magnetite which preponderates as granular masses containing numerous small pits right down to only a few microns in size. While it is impossible to say if all these pits contained gangue which was pulled out during polishing, it is probable that the majority of them are due to the brittle nature of the ore mineral. Nevertheless, the magnetite does contain inclusions of gangue but most of them are large enough to be released by moderately fine grinding. A small percentage of such inclusions, however, are only 74 microns (200 mesh) or less in size, the smallest observed being approximately 24 microns (-560+800 mesh). A relatively negligible amount of hematite is present as rare small grains in magnetite.

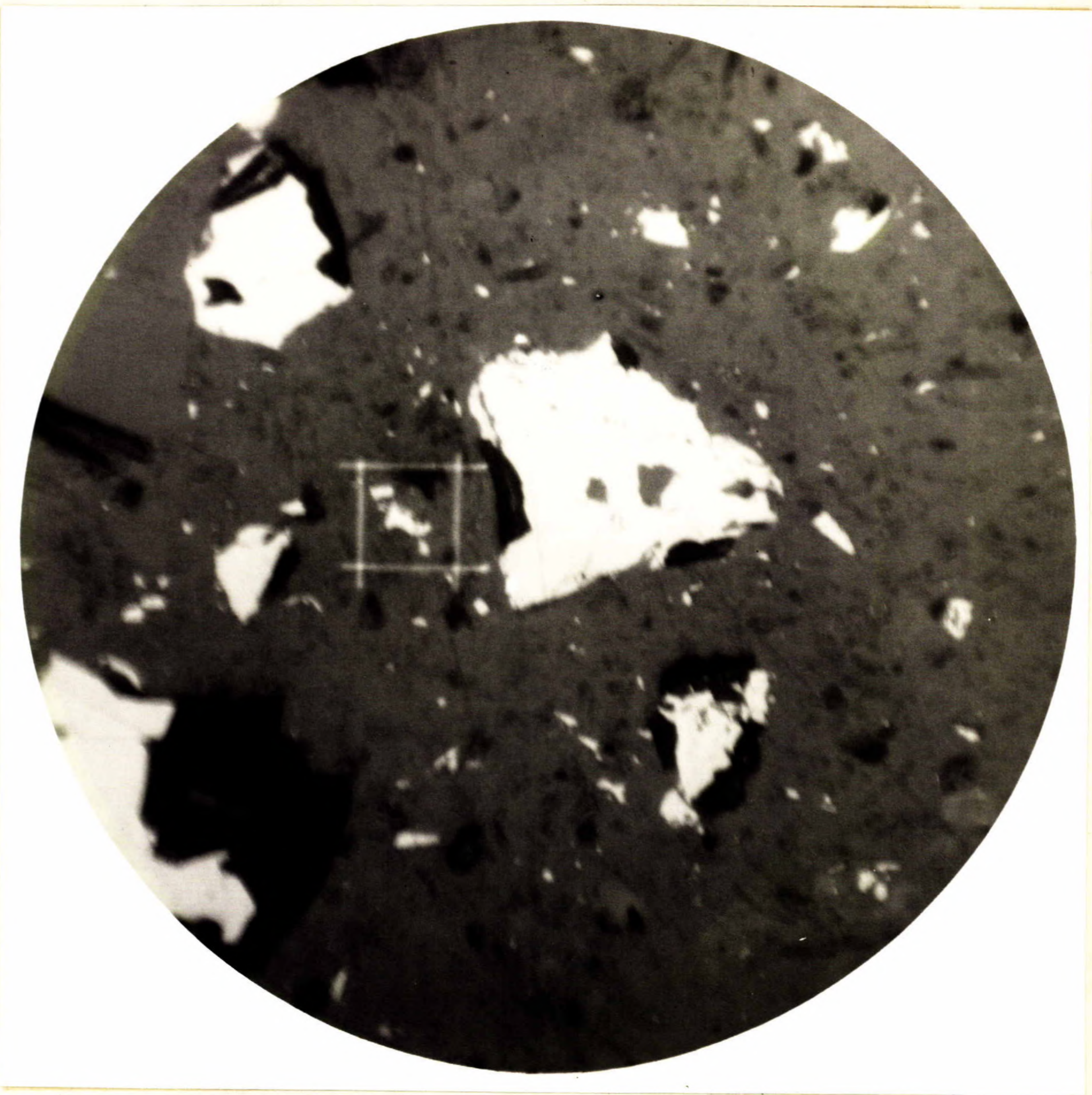
Magnetic Concentrates -

Microscopic examination of ten polished sections from five concentrates showed that magnetite preponderates, as uneven grains which range from about 225 microns (-42+65 mesh) down to only a micron or two in size. Hematite occurs as occasional small particles usually combined with magnetite (see Figure 2). Sulphides (largely pyrite, but pyrrhotite and chalcopyrite are also present) are visible as rare small grains which almost always appear to be free in the mounting medium (bakelite). However, a few tiny particles occur in magnetite, usually with gangue (see Figure 3). A very small percentage of gangue is present in the polished sections, in two ways: (1) as tiny inclusions entirely within magnetite (see Figures 1-3), and (2) as rare small particles which are predominently free in bakelite but are sometimes attached to iron oxides.

(Figures 1, 2, and 3 follow,
on Pages 4, 5 and 6.
(Text is continued on Page 7.)

(Characteristics of the Ore, cont'd) -

Figure 1.



Photomicrograph of polished section from a magnetic concentrate of iron ore from Tomahawk Iron Mines, showing tiny inclusions of gangue (grey) within magnetite (white). The grey matrix is bakelite and pits are black.

The magnification is 200X and a 200-mesh opening is shown in left centre.

(Characteristics of the Ore, cont'd) -

Figure 2.

Photomicrograph of a polished section prepared from a magnetic concentrate of an ore sample submitted by Tomahawk Iron Mines, showing small grains of hematite (white) combined with magnetite (light grey). Note also the tiny, elongated particles of gangue (dark grey) in the magnetite. Bakelite is dark grey and pits are black.

A 200-mesh screen opening is superimposed at 200X magnification.

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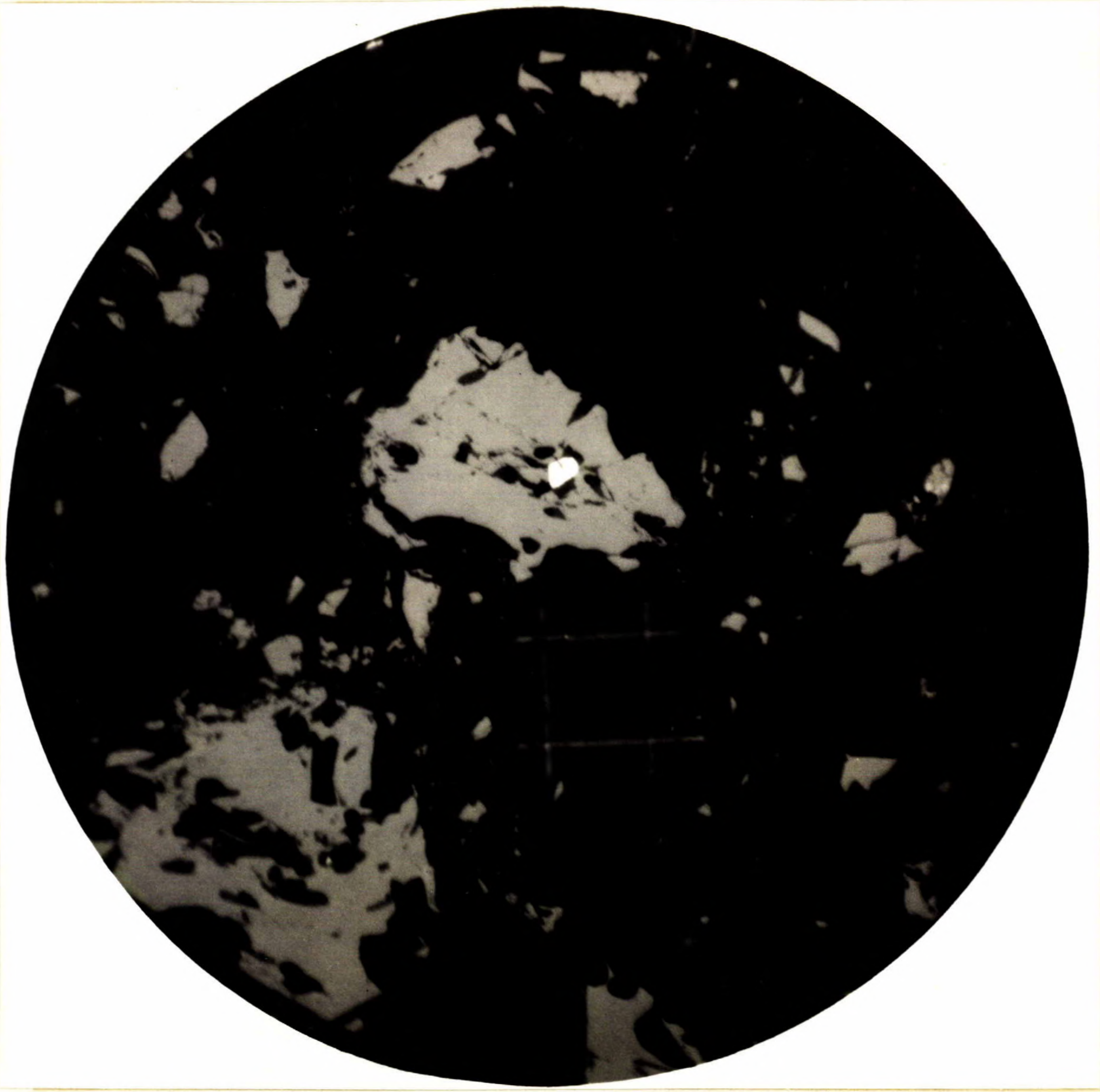
(Characteristics of the Ore, cont'd) -

Figure 3.



This photomicrograph of a polished surface prepared from magnetic concentrate of an ore sample from Tomahawk Iron Mines shows a composite grain of pyrite and chalcopyrite (white) with gangue (dark grey) in magnetite (light grey).

As in Figures 1 and 2, the bakelite matrix is dark grey, pits are black, and a 200-mesh screen opening is shown at a magnification of 200X.

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DETAILS OF INVESTIGATION:

The ore, crushed to pass ¼ inch, was fed at the rate of 720 pounds per hour to a 30 in. x 48 in. ball mill which discharged into a 20 in. x 30 in. Hum-mer 60-mesh screen. The oversize was returned to the ball mill for regrinding while the undersize was passed to the rougher section of a Roche wet magnetic separator which produced a concentrate and a final tailing. This concentrate passed to the cleaner section of the separator, where concentrates and middling were produced.

The magnetic concentrate then was demagnetized and fed to a full-size Wilfley table which produced concentrates and tailing.

RUN NO. 1.

In this run the flow-sheet was as described above, with the magnetic separator middling returned to the separator feed.

The Wilfley table concentrate was split into two products, the No. 1 concentrate being taken from the higher side of the table. Tonnage tests on the products showed that circulating loads were not built up. The ratio of Roche magnetic concentrates to Roche middlings and tailing and table tailing was 1:1.04:1.13:0.09.

The following assays therefore can only be taken as indicative:

| | Acid soluble Fe | $SiO_2$ | Insoluble |
|---|---|---|---|
| | - Per Cent - | | |
| Roche magnetic concentrate - | 71.47 | 0.44 | 0.73 |
| " middling - | 66.80 | - | 5.52 |
| " tailing - | 4.90 | - | 88.84 |
| Table Concentrate No. 1 - | 71.57 | 0.23 | 0.40 |
| " " No. 2 - | 71.57 | 0.35 | 0.59 |
| " tailing - | 68.90 | - | 2.96 |

To determine if any portion of the higher-grade table concentrate contained less silica and insoluble, a screen

(Run No. 1, cont'd) -

analysis was made on Concentrate No. 1.

Results -

| Mesh | Weight, per cent | Assays, per cent Fe | $SiO_2$ | Insoluble |
|---|---|---|---|---|
| Feed (calculated) | 100.0 | 71.65 | 0.22 | 0.38 |
| +100 | 2.0 | 71.02 | 0.62 | 0.88 |
| -100+150 | 21.4 | 71.62 | 0.21 | 0.39 |
| -150+200 | 20.0 | 71.59 | 0.21 | 0.39 |
| -200 | 56.6 | 71.70 | 0.21 | 0.35 |

There is no material difference amongst the various screened products as shown above.

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## RUN NO. 2.

This run was a continuation of Run No. 1, with the exception that the middling obtained from the cleaner section of the Roche magnetic separator was not returned to the circuit.

The immediate effect of this change was a reduction of fully 50 per cent in the volume of concentrates being produced.

One concentrate only was taken off the Wilfley table.

Assays -

| | Fe | $SiO_2$ | Insoluble |
|---|---|---|---|
| | | - Per Cent - | |
| Roche magnetic concentrate - | 71.30 | 0.38 | 0.59 |
| " middling - | 66.26 | 1.88 | 4.60 |
| " tailing - | 2.97 | - | 85.80 |
| Table concentrate - | 71.34 | 0.31 | 0.46 |
| " tailing - | 70.17 | - | 2.54 |

As in the preceding run, a screen analysis was made on the table concentrate.

(Continued on next page)

(Run No. 2, cont'd) -

Results -

| Mesh | Weight, per cent | Assays, per cent Fe | SiO$_2$ | Insoluble |
|---|---|---|---|---|
| Feed (calculated) | 100.0 | 71.66 | 0.26 | 0.46 |
| +100 | 16.7 | 71.55 | 0.28 | 0.47 |
| -100+150 | 31.9 | 71.76 | 0.30 | 0.52 |
| -150+200 | 15.5 | 71.34 | 0.32 | 0.50 |
| -200 | 35.9 | 71.76 | 0.20 | 0.38 |

The middling that was taken out of the above run was dewatered, ground in the ball mill, and passed through the magnetic separator and over the Wilfley table. This was done to note if any reduction of impurities was effected.

Assays -

| | Fe - Per Cent - | Insoluble |
|---|---|---|
| Feed | 68.26 | 4.60 |
| Roche magnetic concentrate | 71.30 | 0.42 |
| " middling | 70.60 | 1.86 |
| " tailing | 10.38 | 78.66 |
| Table concentrate | 71.50 | 0.47 |
| " tailing | 67.84 | 1.62 |

This table concentrate was then re-passed over the Roche magnetic separator to note if any further reduction in impurities was obtained.

Assays -

| | Fe | SiO$_2$ - Per Cent - | Insoluble |
|---|---|---|---|
| Roche magnetic concentrate | 71.53 | 0.21 | 0.33 |
| Roche tailing | 69.96 | - | 2.08 |

A screen analysis was made on the magnetic concentrate.

Results -

| Mesh | Weight, per cent | Assays, per cent Fe | SiO$_2$ | Insol. | Distribution, per cent Fe | SiO$_2$ | Insol. |
|---|---|---|---|---|---|---|---|
| Feed (cal.) | 100.0 | 71.53 | 0.22 | 0.36 | 100.0 | 100.0 | 100.0 |
| +100 | 5.4 | 71.55 | 0.40 | 0.69 | 5.4 | 10.1 | 10.4 |
| -100+150 | 18.8 | 71.54 | 0.26 | 0.48 | 18.8 | 22.9 | 25.0 |
| -150+200 | 19.0 | 71.60 | 0.23 | 0.39 | 19.0 | 20.3 | 20.7 |
| -200 | 56.8 | 71.50 | 0.18 | 0.28 | 56.8 | 46.7 | 43.9 |

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(Details of Investigation, cont'd) -

RUN NO. 3.

This run was similar to Run No. 1 where the Roche middling was returned to the feed of the magnetic separator. The table concentrate was split into two products, Concentrates Nos. 1 and 2.

Operating Data -

| | | |
|---|---|---|
| Feed rate | - | 720 lb./hr. |
| Screen circulating load | - | 391 per cent. |
| Roche magnetic concentrate | - | 440 lb./hr. |
| " middling | - | 976 " |
| " tailing | - | 156 " |
| Table Concentrate No. 1 | - | 150 " |
| " " No. 2 | - | 253 " |
| " tailing | - | 37 " |

Assays -

| | | Fe | $SiO_2$ | Insoluble |
|---|---|---|---|---|
| | | - Per Cent - | | |
| Feed | - | 54.91 | 13.00 | - |
| Roche magnetic concentrate | - | 71.67 | 0.36 | 0.65 |
| " tailing | - | 6.28 | - | 93.44 |
| Table Concentrate No. 1 | - | 71.67 | 0.26 | 0.40 |
| " " No. 2 | - | 71.67 | 0.37 | 0.67 |
| " tailing | - | 66.81 | 1.08 | 0.58 |

Recovery by magnetic concentration = 97.1 per cent.

Recovered as table concentrate = 97.1(-) per cent.

Portions of Table Concentrates Nos. 1 and 2 were re-passed through the Roche magnetic separator to determine whether the silica content could be lowered by such treatment. Portions of the concentrates also were re-tabled with the same object in view.

Results:

Table Concentrate No. 1 Re-passed Through the Magnetic Separator.

| | | Fe | $SiO_2$ | Insoluble |
|---|---|---|---|---|
| | | - Per Cent - | | |
| Feed | - | 71.67 | 0.26 | 0.40 |
| Roche magnetic concentrate | - | 71.76 | 0.22 | 0.42 |
| Roche tailing | - | 68.40 | - | 2.26 |

Recovery = 97.4 per cent.

There was a slight reduction in the silica

(Run No. 3, cont'd) -

content. The analyses of the insoluble are erratic but show some elimination.

Table Concentrate No. 2 Re-passed Through the Magnetic Separator.

| | Fe | $SiO_2$ | Insoluble |
|---|---|---|---|
| | - Per Cent - | | |
| Feed - | 71.67 | 0.37 | 0.67 |
| Roche magnetic concentrate - | 71.57 | 0.34 | 0.62 |
| Roche tailing - | 64.66 | - | 7.02 |

Here again there is a slight reduction in the silica content.

Re-tabling of the concentrates did not lower the impurities in either product.

A typical analysis of the product obtainable is as follows:

| | | Per Cent |
|---|---|---|
| Total iron (Fe) | - | 71.83 |
| Silica ($SiO_2$) | - | 0.24 |
| Alumina ($Al_2O_3$) | - | 0.13 |
| Lime (CaO) | - | 0.03 |
| Magnesia (MgO) | - | 0.05 |
| Manganese oxide (MnO) | - | 0.10 |
| Titanium dioxide ($TiO_2$) | - | 0.01 |
| Vanadium (V) | - | Trace. |
| Water ($H_2O$) | - | 0.01 |
| Sulphur (S) | - | None detected. |
| Phosphorus (P) | - | " " |

CONCLUSIONS:

Magnetic separation with two stages of cleaning, followed by table concentration with splitting the table concentrate into two parts, can be expected to supply a product containing 71.76 per cent iron, 0.22 per cent silica, and 0.42 per cent insoluble. Approximately 37 per cent of the iron in the feed can be recovered as a product of this grade. The

(Conclusions, cont'd) -

remainder of the iron recovered has a slightly higher percentage of impurities.

Microscopic examination showed the iron mineral to be practically all magnetite, 71.76 per cent iron, which is equivalent to 99.17 per cent magnetite. The remaining 0.83 per cent impurities is made up of acid-soluble and insoluble impurities.

The gangue mineral is tremolite or, more probably, actinolite, a calcium-magnesium-iron amphibole with the chemical formula resembling $Ca(Mg.Fe)_3(SiO_4)_3$.

On reducing the magnetite to metallic iron, none of the impurities, apart from possibly a very small quantity of oxygen and carbon dioxide, would be eliminated.

Therefore, with 100 per cent reduction of the magnetite to metallic iron there would be 71.76 parts of iron and 0.83 parts of impurities. The resulting product thus would contain 98.86 per cent metallic iron and 1.14 per cent impurities. As 100 per cent reduction is practically impossible to attain, the percentage of metallic iron in the finished product would be lowered by these unreduced oxides.

Iron powder for bearings and parts requiring strength should be 99 per cent metallic iron or better. The product obtainable from ore of the same grade and character as that investigated and covered by this report does not meet the present specifications for high-grade iron powder.

Whether or not the product obtainable would be suited for the manufacture of poorer quality parts depends on what success is met with in the reduction of the magnetite to metallic iron.

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