IRONSAND CONCENTRATION PROCESSES AT NEW ZEALAND STEEL LIMITED

D Thors, C W Cutten, N A MacArthur and S J Griffiths

1. GENERAL

A Government sponsored investigation into the possibility of producing steel from the titanomagnetite in the blacksands along New Zealand's west coast was undertaken in 1964. As a result, New Zealand Steel Limited was formed and the direct reduction/electric arc steel making process was commissioned in 1970. The plant was located at Glenbrook, some 65 km from Auckland and 20 km from the large ironsand deposit at Waikato North Head. See Figure 1.

New Zealand Steel has now developed this process to convert titanomagnetite into steel using the non-coking, high reactive coals of the Waikato field as the solid reductant (1). To meet the planned steel production of 140,000 t/a, mining has been carried out by motor scrapers at Waikato North Head at a rate of 1.5 M t/a of sand and the mineral concentrate has been separated out from the sand using a combination of wet magnetic and gravity separators.

A study was also carried out on the Taharoa ironsand deposit, 200 km to the south, to supply titanomagnetite directly offshore to the Japanese steel industry. From 1972 to 1977 concentrate was shipped at an average rate of 1.2 M t/a. At that time the plant was expanded to meet a contract requirement of 2.1 M t/a, making it necessary to build a second mining and concentrating plant (2).

In 1982 a project to expand the Glenbrook steelworks was approved. Primary steel production will be expanded to 730,000 t/a and the expansion will also include hot and cold rolling mills. To produce the required 1.5 M t/a of titanomagnetite concentrate, the mining system planned will utilise bucket wheel excavators, while the concentration plant, the fourth the company will have built, will follow the company's proven magnetic/gravity flowsheet.

This paper discusses the various flowsheets developed and operated by the company and the reasoning behind the latest circuit.

2. GEOLOGY

The Taharoa and Waikato North Head deposits, worked by New Zealand Steel, have reserves of 300 million and 100 million tonnes of titanomagnetite respectively. The titanomagnetite in both deposits is derived from marine erosion of the andesites and other rocks produced in the volcanics to the west of Mt Egmont.

Although derived from the same source rock, the deposits have a number of differences, the most important being that the Waikato
North Head deposit contains high grade clay bound horizons which are not present at Taharoa.

The only economic mineral in the deposits is titanomagnetite, a magnetite (Fe$_3$O$_4$)–ulvospinel (Fe$_2$TiO$_4$) solid solution species (3). It contains up to 62% Fe and 8% TiO$_2$.

The gangue minerals are predominantly ferromagnesians, pyroxenes and feldspars, which are normally coarser than the titanomagnetite, being +0.150 mm compared with the average size for titanomagnetite per grain of +0.100 mm.

Typical concentrate assays from Waikato North Head and Taharoa are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Wt %</th>
<th>FeO</th>
<th>CaO</th>
<th>SiO$_2$</th>
<th>TiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>MgO</th>
<th>V$_2$O$_5$</th>
<th>MnO</th>
<th>P</th>
<th>S</th>
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<tbody>
<tr>
<td>WNH*</td>
<td>58.0</td>
<td>1.0</td>
<td>3.7</td>
<td>8.0</td>
<td>4.2</td>
<td>3.0</td>
<td>0.6</td>
<td>0.6</td>
<td>0.06</td>
<td>0.004</td>
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<tr>
<td>Taharoa</td>
<td>56.4</td>
<td>1.4</td>
<td>4.4</td>
<td>7.2</td>
<td>3.8</td>
<td>3.3</td>
<td>0.5</td>
<td>0.6</td>
<td>0.16</td>
<td>0.004</td>
<td></td>
</tr>
</tbody>
</table>

* Waikato North Head
3. WAIKATO NORTH HEAD

3.1 Original Flowsheet

The original concentration process at Waikato North Head consisted of wet scrubbing, primary magnetic separation at 900 gauss, ball milling of the magnetic concentrate, secondary magnetic separation at 500 gauss and filtration of the final concentrate. The final concentrate particle sizing was 90% through 40 microns, with a grade of 60.5% Fe. Designed capacity of the plant was 31 t/h of concentrate. The plant operated in this configuration from commissioning in 1969 until mid-1972.

Initially, the pelleted concentrate was reduced to sponge iron in a rotary kiln but severe degradation occurred to the green balls in the kiln and much concentrate was lost in the waste gas. A further problem was kiln accretion caused by the formation of hard, dense, fine-grained, metalised layers on the walls of the kiln.

In 1971 a test was undertaken in the kiln using the unground magnetic iron sand concentrate. This proved successful and in mid-1972 a further full scale test was carried out over one operating week. Results were most encouraging and the decision was made to change permanently to this mode of operation.

3.2 Modified Flowsheet

The Waikato North Head plant was then set up with the primary wet magnetic separators followed by three banks of eight twin spirals. It was fed at some 240 t/h and produced 31 t/h concentrate. Later it was found necessary to install a screen with 3 mm apertures after the magnetic separators to remove the clay agglomerates from the magnetic separators that the ball mills had previously dealt with.

A bank of scavenger spirals was subsequently added to improve recovery. The resulting flowsheet is shown in Figure 2a.

In 1978 primary iron making improvements required a 20% increase in concentrate demand up to 240,000 t/a. This was achieved at minimum cost in the magnetic section by replacing the second drum in the 900 mm diameter separators with a 600 mm drum from the old secondary magnetic separators, unused since 1972. The free 900 mm drum was then paired with another 600 mm drum to make a fifth two drum separator. Careful redesign of the tanks made this move successful, with the added benefit that some
of the clay balls were rejected in the lower field strength second drums of these modified units.

In the gravity circuit, a Reichert cone was tested over twelve months and eventually installed, replacing the primary spirals. The spirals were then used in a tertiary scavenger stage. This modified flowsheet required less water, as the cone was fed at 60% pulp density, compared with the spirals at 25% - 35% (4).

Since 1978 a number of rearrangements of the basic cone spiral gravity circuit have been tried to find the best way of handling the clay-bound particles which report to the gravity middlings. At present, as shown in Figure 2b, a Wright tray is being used for tertiary gravity separation.

Attritioning tests have established an increased recovery of grade mineral and this modification will be included in the expanded plant.

4. TAHAROA

4.1 No. 1 Plant Flowsheet

This was commissioned in 1972 to produce titanomagnetite concentrate of +56.0% Fe at 1.2 M t/a for the Japanese market. Mining at 700 t/h by cutter suction dredging with a floating concentrator was selected for the thick loose dune sands at Taharoa (2).

Following testwork (5) a flowsheet was selected using rougher gravity separation and magnetic cleaning. This is shown in Figure 2d.

Gravity roughing was by Reichert cones which produced a concentrate, a middling and a tailing. The concentrate was passed to 900 mm diameter, 900 gauss (g) double drum wet magnets and then to 600 mm, 450 g wet Mortsell magnetic separators for final cleaning. The primary cone tailing was rejected.

The cone middling, plus the primary Mortsell tailing, was passed to a scavenger or middlings circuit consisting of Reichert cones, a 900 mm single drum magnet and a further Mortsell magnet. In normal grade feeds the scavenger Mortsell concentrate was sent to final concentrate, otherwise it was recycled to the primary magnets.

By 1977 mining had advanced into lower grade areas and concentrate grades declined. The magnetic circuit was unable to selectively separate the larger numbers of middling composite particles, so that concentrate grades were low and large recycle flows were built up (4).
A pilot flowsheet, using gravity to replace magnetic cleaning, was designed and tested (4) and is shown in Figure 2e. This flowsheet is now applied in the No. 1 Concentrator.

The rougher cones take four cuts; two concentrates, a middling and a tailing. The first concentrate fraction passes directly to wet double drum magnets which produce only final tailings and final concentrate. No magnetic discrimination of composites is required.

The second rougher concentrate passes to the cleaner cones which also produce a concentrate suitable for the final double drum magnets. The rougher middlings pass to scavenger cones but the scavenger cone concentrate is recycled back to the cleaner cones. Rougher tails are rejected.

With the modified flowsheet grade has been assured and recovery has improved. A comparison of performance with the original and modified flowsheets is given below in Table 1.

**TABLE 1: PERFORMANCE OF TAHAROA CONCENTRATORS**

<table>
<thead>
<tr>
<th></th>
<th>No. 1 Concentrator</th>
<th>No. 2 Concentrator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original</td>
<td>Modified</td>
</tr>
<tr>
<td></td>
<td>% TM</td>
<td>% Fe</td>
</tr>
<tr>
<td>Head Feed</td>
<td>45</td>
<td>29.7</td>
</tr>
<tr>
<td>Concentrate</td>
<td>97</td>
<td>56.2</td>
</tr>
<tr>
<td>Tailings</td>
<td>18</td>
<td>15.9</td>
</tr>
<tr>
<td>Feed rate t/h</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>74</td>
<td>65</td>
</tr>
</tbody>
</table>

* TM: Titomamagnetite

4.2 No. 2 Concentrator

The No. 2 Concentrator was commissioned in early 1978 for the working of thin shallow sand that could not be dredged. Bulldozers are used to push the sand into a buried feeder conveyor that feeds into a slurry bin and then the concentrator. A feed rate of 360 t/h is normally achieved (2).

The start-up flowsheet was similar to that in Figure 2e and included four rougher cones, two scavengers and two cleaner
cones. It also contained a scavenger wet double drum magnet that produced final concentrate from scavenger cone concentrate. As mining passed into lower grade feed it became necessary to redirect this scavenger cone concentrate to the cleaner cones.

Results based on the initial scavenger layout are shown in Table 1.

The No. 2 Concentrator made use of the new generation 1200 mm diameter wet drum magnets, instead of the older 900 mm units. These larger units achieve a small but useful increase in discrimination of composites for a loss of 1% magnetic recovery and have allowed the rougher cones to be operated with their splitters wider. The result has been a 4% better overall recovery.

5. PROPOSED FLOWSHEET FOR WAIKATO NORTH HEAD

In the expansion plan, production of iron sand concentrate will be increased six times from the current 225,000 t/a of concentrate to 1.5 Mt/a. The opportunity is being taken at this time to redesign the flowsheet and testwork has therefore been concentrated in three main areas:

5.1 Whether magnetic separation is to come before or after the gravity separation stages.

5.2 Whether the Reichert cones are comparable with the modern, high capacity, high density, spirals, and,

5.3 How to retain clay slimes in tailings and still maintain a stable, high angled tailings stack.

Essentially, little testwork was undertaken to establish the magnetic versus gravity separation in the first stage of the plant. In New Zealand Steel's experience there are advantages in lower grade feed in being able to bulk the material down rapidly through the magnetic separating process. At Taharoa, where the grade is much higher, the bulk handling problems are not quite so important. The study therefore established quite clearly that in the Waikato North Head deposit it was preferable to put the magnetic separators ahead of the gravity units in the circuit.

Considerable testwork was undertaken at Waikato North Head on a number of different manufacturers' spirals. In addition, Mineral Deposits Limited of Southport, Australia, were commissioned to undertake tests on cones. Metallurgically, it was established that either cones or spirals could equally well undertake the gravity concentration operation but there were definite economic advantages in putting cones in as the primary and secondary gravity separating units in the Waikato North Head project. In the tertiary gravity circuits where the capacity is
much reduced, the spirals will be retained.

A pilot scale test was established to check on the slimes contents of the tailings from the Waikato North Head operation and the company is currently undertaking a full scale test programme to confirm the information obtained in the pilot work. Because the sand is not at this stage ground in any form, and the non-magnetic fraction passes straight through to the tailings, the final tailings resemble very much the original sand feed and there would appear to be no major difficulties in obtaining stable, high angled, tailings stacks.

The other major problem existing between the present and the proposed operations is the loss of sand blending facilities resulting from the changes made from mining with a number of elevating scrapers to two only bucket wheel excavators. To maintain uniform conditions in the concentration plant it is important to try to maintain a constant tonnage of magnetics in the raw feed and at Waikato North Head, where the grade may well range from 12% to 30%, the feed rate could also vary from 1200 t/h to 2500 t/h. A feed stockpile with 4 hours live load is designed into the plant and will allow a limited amount of blending, but most of the fluctuations will have to be taken up in plant.

In the plant the sand feed will initially be screened at 6 mm and the oversize will pass into the existing scrubber. Undersize will then drop through into the main slurry feed bin. From this bin two pumps will feed the two parallel 1250 t/h circuits made up of magnetic separators, cones and spirals. The schematic flowsheet is shown in Figure 2c.

Magnetic concentrates from the double drum (1200 dia x 3000 mm) long magnetic separators will be screened at 3 mm before being pumped to the gravity circuits. Final concentrates will be taken from the primary cones and from the first stage of the secondary cones, while the lower grade middlings will normally be directed to an attrition circuit.

The plus 3 mm fraction from the magnetic separator concentrate will also be attritioned and recycled, after magnetic scavenging, to the secondary cones.

Tailings will be disposed of in the older mined-out workings until the new bucket wheel system advances sufficiently to allow tailings stacking to be carried out behind the faces. Water will be reclaimed from the tailings and will supplement the existing river water supply.

6. CONCLUSION

New Zealand Steel Limited has tested and operated a number of flowsheets for the concentration of titanomagnetite since it started operations over twelve years ago. Due to differences
between the deposits two contrasting approaches have been used; magnetic roughing followed by gravity cleaning at Waikato North Head, and gravity roughing and cleaning followed by magnetic final cleaning at Taharoa.

Both approaches have been successful and both have been confirmed by continuing in-plant testwork.

Many types of gravity and magnetic equipment have also been tried over the years. It has been found that the metallurgical superiority of one model over another was often not great and equipment selection has been determined on economic or materials handling grounds in these cases.

REFERENCES


FIGURE 2: Titanomagnetite Concentration Flowsheets Used by New Zealand Steel Limited