**OFFICIAL APPLICATION NO.** | **LODGING DATE: PROVISIONAL** | **ACCEPTANCE DATE**
---|---|---
21 01 | 154458 | 47 13.2.96

**INTERNATIONAL CLASSIFICATION** | **LODGING DATE: COMPLETE** | **GRANTED DATE**
---|---|---
51 C22B | 23 31st May, 1995 | 1996. 04. 26

**FULL NAME(S) OF APPLICANT(S)/PATENTEE(S)**

MINTEK. A legal body organised and existing under the laws of the Republic of South Africa.

**APPLICANTS SUBSTITUTED:**

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**ASSIGNEE(S)**

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**FULL NAME(S) OF INVENTOR(S)**

Derek Alan HAYMAN, Glen Michael DENTON.

**PRIORITY CLAIMED**

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<th>COUNTRY</th>
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<td>10th June, 1994</td>
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**TITLE OF INVENTION**

THE RECOVERY OF METAL VALUES FROM SLAGS.

**ADDRESS OF APPLICANT(S)/PATENTEE(S)**

200 Hans Strijdom Drive, Randburg, Transvaal Province, Republic of South Africa.

**ADDRESS FOR SERVICE**

JOHN & KERNICK, VAN DER STEL BLDG., PRETORIUS STR., PRETORIA

**PATENT OF ADDITION NO.**

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**FRESH APPLICATION BASED ON**

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WHEREAS

MINTEK,

(Hereinafter called "the Patentee")

(Hieronder "die Patenthouer" genoem)

has applied to me for the grant of a patent in respect of an invention described and claimed in the complete specification

aansoek by my gedoen het om die verlening van 'n patent ten opsigte van 'n uitvinding wat beskryf is en waarop aanspraak

deposited at the Patent Office under the above-mentioned number, a copy of which is annexed, together with the relevant

gemaak word in die volledige spesifikasie wat by die Patentkantoor onder bovermelde nommer ingediend is en waarvan 'n

Form P.2;

afskrif aangeheg is tesame met die betrokke Vorm P. 2;

NOW THEREFORE these Letters Patent are to grant to the Patentee a patent, the effect of which shall be to grant to the

SO IS DIT dat hierdie Patentbrief aan die Patenthouer 'n patent verleen wat die uitwerking het dat, behouens die

Patentee in the Republic, subject to the provisions of the Act, for the duration of the patent, the right to exclude other persons

beplings van die Wet, aart die Patenthouer vir die duur van die patent in die Republiek die reg verleen word om ander

from making, using, exercising or disposing of the invention, so that he shall have and enjoy the whole profit and advantage

persone uit te sluit van die vervaardiging, aanwending, uitoefening of van die handsetting van die uitvinding, sodat hy al die

accruing by reason of the invention.

wins en voordeel wat uit die uitvinding voortspruit, verkry en geniet.

IN TESTIMONY WHEREOF the seal of the Patent Office has been affixed at Pretoria with effect from the

TER BETUIGING WAARVAN die seël van die Patentkantoor hierop te Pretoria aangebring is met ingang van die

24th day of APRIL nineteen hundred and

dag van aanduensend negehonderd NINETY SIX

[See overleaf]
[Blaai om]
1. The patent remains in force only if the required renewal fees are paid annually after the third year of the date of application.
   Die patent is geldig slegs indien die vereiste hernuwingsgeldige jaarliks, na die derde jaar vanaf die datum van aanooik betaal word.

2. This document is not valid unless sealed with the seal of the Patent Office, PRETORIA.
   Hierdie dokument is nie geldig nie tensy geseël met die seël van die Patentskantoor, PRETORIA.
Dear Sir / Madam

We have much pleasure in enclosing the Letters Patent Document issued in respect of the above application the particulars of which are as follows: -

PATENTEE: MINTEK

PRIORITY CLAIMED: ZA 94/3729 10th June, 1994

FILING DATE: 31st May, 1995

TERM OF PATENT: Twenty years from the date of filing

PATENT EXPIRES: 31st May, 2015

RENEWAL FEES: Due annually starting three years after the date of filing

N.B. While we do make a practice of sending reminders in regard to the dates on which renewal fees become due for payment we cannot accept any responsibility for failure to do so or for the fact that a reminder may not be received by the due date.

Yours faithfully

JOHN & KERNICK.
**OFFICIAL APPLICATION NO.** | 21 | 01 | 154458
---|---|---|---
**LODGING DATE:** | 22 | | PROVISIONAL
**ACCEPTANCE DATE:** | 47 | | 13-2-96

**INTERNATIONAL CLASSIFICATION** | 51 | .C22B
---|---|---
**LODGING DATE:** | 23 | | COMPLETE
**GRANTED DATE:** | 1995 | | 2-6

**FULL NAME(S) OF APPLICANT(S)/PATENTEE(S)**
MINTEK. A legal body organised and existing under the laws of the Republic of South Africa.

**APPLICANTS SUBSTITUTED:**
- [ ]

**DATE REGISTERED:**
- [ ]

**ASSIGNEE(S)**
- [ ]

**DATE REGISTERED:**
- [ ]

**FULL NAME(S) OF INVENTOR(S)**
Derek Alan HAYMAN, Glen Michael DENTON.

**PRIORITY CLAIMED**
- **COUNTRY**: ZA
- **NUMBER**: 94/3729
- **DATE**: 10th June, 1994

**N.B.** Use International abbreviation for country (See Schedule 4)

**TITLE OF INVENTION**
THE RECOVERY OF METAL VALUES FROM SLAGS.

**ADDRESS OF APPLICANT(S)/PATENTEE(S)**
200 Hans Strijdom Drive, Randburg, Transvaal Province, Republic of South Africa.

**ADDRESS FOR SERVICE**
JOHN & KERNICK, VAN DER STEL BLDG., PRETORIUS STR., PRETORIA

**J & K REF:** P 12403 ZA

**PATENT OF ADDITION NO.**
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** REMARKS: (FOR OFFICE USE ONLY)**
**COMPLETE SPECIFICATION**

(Section 30(1) - Regulation 26)

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<td>THE RECOVERY OF METAL VALUES FROM SLAGS.</td>
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THE RECOVERY OF METAL VALUES FROM SLAGS

FIELD OF THE INVENTION

This invention relates to the recovery of metal values from slags, and, more particularly, from slags which are produced in matte production processes, such as those produced in the treatment of a concentrate for the recovery of nickel and copper therefrom. Still more particularly, but not exclusively, the invention is concerned with the recovery of cobalt from slags produced in matte production processes. This includes both the slag product in the production of a green /matte, and
matte, and the converter slags produced in the subsequent treatment of a green matte to produce a white matte.

BACKGROUND TO THE INVENTION

Sulphide mattes are produced in many different metal recovery processes and, most particularly, in the production of nickel and copper from flotation or other concentrates containing same.

Generally, a green matte is firstly produced. The slag from the production of such green matte is often discarded. There are thus vast quantities of such slags in dumps at certain plants.

The green matte is then blown in a converter to produce a white matte and another slag, herein termed the converter slag.

Both slags, but in particular the converter slag, often contain a significant quantity of cobalt, in addition to certain amounts of copper, nickel and, usually, significant proportions of iron.

/The converter
The converter slag is usually recycled to the furnace in which the green matte is produced and some of the metal values contained therein are recovered, whilst a substantial proportion is lost. This process also has the disadvantage that the oxides are recycled to the sulphide treatment step thereby re-mixing the sulphide and oxide cycles.

OBJECT OF THE INVENTION

It is the object of this invention to provide for the improved recovery of metal values contained in slags emanating from matte production processes and, in particular, but not exclusively, from a converter slag.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a process for the recovery of metal values from a feed slag which contains metal values and which emanates from a matte production process, the process comprising sub-dividing the feed slag and charging it into an open arc d.c. furnace having an elevated electrode and a molten bath acting as the

/other electrode.
other electrode, or charging the feed slag in a molten state into the furnace, treating the feed slag in the furnace with carbonaceous reductant to form a metal phase and a slag phase, recovering the metal phase, and treating the metal phase for the recovery of the desired metal values therein.

Further features of the invention provide for the feed slag to be a converter slag produced in a nickel and copper recovery process during blowing of a green matte to produce a white matte; for the amount of carbonaceous reductant employed to be less than the stoichiometric amount required to reduce all metal oxides in the feed slag to metal and, more particularly, for the amount of carbonaceous reductant to be chosen so as to limit the reduction of iron oxides present in the feed slag to thereby enhance the proportion of other metal values, in particular cobalt and, most particularly, for the amount of carbonaceous reductant employed to be from 30% to 60% of said stoichiometric amount; for the reduction to take place at a temperature of at least 1400° C and preferably 1500 - 1600° C; for the carbonaceous reductant and feed slag to be either fed simultaneously to the furnace or, more preferably,
for the feed slag to be pre-melted prior to feeding of the carbonaceous reductant to the furnace; and for the molten bath to be employed as the anode in the d.c. electrical circuit.

The invention still further provides for the metal produced in the reduction process to be leached, conveniently with spent electrolyte from a copper or nickel electrowinning process; and for iron to be precipitated out of the resultant leach solution by decreasing the pH appropriately. The cobalt, copper and nickel can then be separated from each other and recovered using any suitable hydro-metallurgical process.

The invention also provides a matte production process in which a green or a white matte is produced in a smelter and the resultant slag is treated by a process defined above.

In order to test the invention, various experiments were carried out and, in order that the invention may be more fully understood, certain of such experiments will be described below.
DETAILED DISCUSSION OF THE INVENTION
AND EXPERIMENTAL TEST RESULTS

In experimental tests conducted in order to initially
demonstrate operation of the invention, a converter
slag sample, which had certain inclusions of matte
therein, was treated according to the invention. The
slag and matte had the following compositions:

ANALYSIS OF THE RAW MATERIALS

<table>
<thead>
<tr>
<th>Analyses (mass %)</th>
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<tbody>
<tr>
<td>Co</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Slag</td>
</tr>
<tr>
<td>Matte</td>
</tr>
</tbody>
</table>

The carbonaceous reductant was a sub-divided coal which
had the following analysis:

COAL ANALYSIS

<table>
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<th>Proximate analysis</th>
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<tr>
<td>Moisture, %</td>
<td>0.8</td>
</tr>
<tr>
<td>Volatiles, %</td>
<td>25.0</td>
</tr>
<tr>
<td>Ash, %</td>
<td>11.9</td>
</tr>
<tr>
<td>Fixed carbon, % (by diff.)</td>
<td>62.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ash analysis</th>
<th></th>
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<tbody>
<tr>
<td>Total silica, as SiO2 %</td>
<td>42.6</td>
</tr>
<tr>
<td>Aluminium, as Al2O3 %</td>
<td>26.7</td>
</tr>
<tr>
<td>Total iron, as Fe2O3 %</td>
<td>15.3</td>
</tr>
<tr>
<td>Calcium, as CaO %</td>
<td>6.27</td>
</tr>
<tr>
<td>Magnesium, as MgO %</td>
<td>0.25</td>
</tr>
<tr>
<td>Sulphur</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>102.3</td>
</tr>
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</table>
The tests were conducted in a 200kVA open arc furnace which employed the molten bath as the anode, and a single, elevated electrode with feeding being effected from the top of the furnace. In order to commence operation of the furnace an 8 hour warm up period was employed during 10kg of converter matte and 80kg of converter slag were melted down. At the end of the warm up period the heel material was tapped, after which a number of batches of converter slag and reductants were treated with different parameters and the following results were achieved. For this purpose as much of the matte as was reasonably possible was removed from the slag by hand.

Operating at a total power of 100kW (made up of a heat loss estimate of 55kW and a specific energy requirement of 0.15kWh/kg of feed) and an operating temperature of 1509°C an alloy was produced having an analysis of

4.62% cobalt
6.74% copper
28.55% nickel, and,
44.27% iron.

The slag, on the other hand, contained

0.28% cobalt

/ 0.38% copper,
0.38% copper, and
0.40% nickel

Feeding of the slag and reductant were carried out simultaneously and the amount of carbonaceous reductant used was 6% by weight of the converter slag, i.e. 34.3% of the stoichiometric amount which would have been required to reduce all the metal oxides present in the slag.

In a second series of tests in which the coal addition was increased to 8% (45.7% of stoichiometric) and the specific energy requirement raised to approximately 0.55kWh/kg of feed, the average tapping temperature was 1489°C.

The alloy produced had a composition of

- cobalt 4.23%
- copper 5.74%
- nickel 24.52%, and,
- iron 50.86%.

The slag contained

- cobalt 0.23%
- copper 0.36%, and,
- nickel 0.31% respectively.

/ It is
It is to be noted that the increase in reductant resulted in an increased dilution by the iron.

In a subsequent series of tests 6% coal (34.3% of stoichiometric) was added only after the slag addition had been melted down over a period of a half an hour. The tapping temperature was 1465°C and the alloy produced had a composition of

5.18% cobalt,
7.91% copper,
34.17% nickel, and,
35.61% iron.

The slag contained

0.29% cobalt
0.35% copper, and
0.33% nickel.

A still further series of tests employed 8% by weight of the coal and, in this case, the tapping temperature was even lower at 1412°C. The alloy produced contained

5.52% cobalt,
8.34% copper,
34.9% nickel, and,
36.01% iron

/ The slag
The slag contained

cobalt 0.25%
copper 0.30%, and,
nickel 0.17%.

Larger scale tests were then carried out in a 500kW open arc DC furnace. In all cases these runs were carried by melting the slag first and adding the carbonaceous reductant to the molten slag subsequently. The reason for this is that it is envisaged that in practice, molten slag from a matte production process will immediately be treated according to the invention while still in its molten, or at least hot, state.

In each case, accordingly, the sub-divided solid slag was firstly fed to a molten bath in the preheated furnace at a rate automatically controlled to ensure that the feed and energy inputs were balanced and to provide a constant temperature of operation. After the batch of slag had been added to the furnace the sub-divided coal was then added over a period of time under similar conditions.

/ In this
In this case the slag had an average composition of 0.93 mass percent Co; 0.49 mass percent Cu; 1.47 mass percent Ni; 50.8 mass percent Fe; 29.2 mass percent SiO₂; 0.18 mass percent CaO; 0.22 mass percent MgO; 0.4 mass percent Al₂O₃; and 1.07 mass percent S.

The coal analysis, on average, had a moisture content of 0.2 mass percent; 26.2 mass percent volatiles; 11.35 mass percent ash; and 62.45 mass percent fixed carbon.

Runs were carried out under five different conditions and the results, on the basis of cobalt recovery, are set out below in Tables 1(a) and 1(b).

**Main Factors Affecting Cobalt Recovery - Table 1(a)**

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>BATCH MASS (kg)</th>
<th>MASS COAL BY WEIGHT</th>
<th>% of STOICHIOMETRIC</th>
<th>COBALT RECOVERY</th>
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<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>8</td>
<td>43.5</td>
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<td>5</td>
<td>1000</td>
<td>9</td>
<td>49.0</td>
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/Main Factors
MAIN FACTORS AFFECTING COBALT RECOVERY - TABLE 1(b)

<table>
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<tr>
<th>CONDITION</th>
<th>MELT DURATION (min)</th>
<th>REDUCTION DURATION (min)</th>
<th>TOTAL TIME (min)</th>
<th>MELT TEMP °C</th>
<th>TAP TEMP °C</th>
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<td>215.1</td>
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<td>150.5</td>
<td>266.0</td>
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It will be noted that coal additions of at least 9% (49.0% of stoichiometric) gave cobalt recoveries of greater than 80% under suitable conditions.

It will be understood that numerous different parameters and operating conditions may be used without departing from the scope of the invention. Also, the invention is not limited to the recovery of metals identified above. Also, the slag may be a slag produced in the green matte production furnace.

/ CLAIMS
1. A process for the recovery of metal values from a feed slag which contains metal values and which emanates from a matte production process, the process comprising sub-dividing the feed slag and charging it into an open arc d.c. furnace having an elevated electrode and a molten bath acting as the other electrode, or charging the feed slag in a molten state into the furnace, treating the feed slag in the furnace with carbonaceous reductant to form a metal phase and a slag phase, recovering the metal phase, and treating the metal phase for the recovery of the desired metal values therein.

2. A process as claimed in claim 1 in which the feed slag is a converter slag produced in a nickel and copper recovery process during blowing of a green matte to produce a white matte.

/3. A process
3. A process as claimed in either of claims 1 or 2 in which the amount of carbonaceous reductant employed is less than the stoichiometric amount required to reduce all metal oxides in the feed slag to metal.

4. A process as claimed in claim 3 in which the amount of carbonaceous reductant is from 30% to 60% of said stoichiometric amount.

5. A process as claimed in any one of the preceding claims in which the reduction takes place at a temperature of at least 1400° C.

6. A process as claimed in claim 5 in which the said temperature is from 1500° C to 1600° C.

7. A process as claimed in any one of the preceding claims in which the carbonaceous reductant and feed slag are fed simultaneously to the furnace.

8. A process as claimed in any one of claims 1 to 6 in which the carbonaceous reductant is fed to the furnace subsequent to the feed slag being premelted therein.

/9. A process
9. A process as claimed in any one of the preceding claims in which the molten bath is employed as the anode in the d.c. electrical circuit.

10. A process as claimed in any one of the preceding claims in which the metal produced in the reduction process is leached followed by decreasing of the pH to precipitate iron.

11. A process as claimed in claim 10 in which leaching is effected using spent electrolyte from a copper or metal electrowinning process.

12. A composite process comprising a matte production process in which either white or green matte is produced in a smelter and the resultant slag is treated as the feed slag by a process as claimed in any one of claims 1 to 11.

13. A process for the recovery of metal values from a feed slag substantially as herein described and exemplified.

DATED on this the 31ST DAY OF MAY 1995.

JOHN & KERNICK
for the Applicant

AMENDMENTS DATED THIS 29TH DAY OF AUGUST 1996.

JOHN & KERNICK
FOR THE APPLICANT