

CHEMICAL COMPOSITION OF PROCESS OUTPUTS

This Appendix details the qualitative analysis of each of output in the Mt Grace magnesium thermic reduction process. Quantities of each procedural output are given in the main text of the EIS. Some details of the process are subject to confidentiality provisions under the terms of Mt Grace's License Agreement with Mintek and cannot be published.

Stages of the mining and plant process are:

1. Mining
2. Crushing and Screening
3. Calcining
4. Furnace and Condenser
5. Refining and Casting
6. Sludge Processing
7. Condenser Residue Treatment

1. Mining

The mining operation will deliver run-of-mine ore to the ROM pad and waste rock to the waste dump. The waste rock has different components that can be generally broken into: overburden; waste magnesite; and Whites Formation rock. The expected proportional volume of overburden is 20%, waste magnesite is 75% and Whites Formation is 5%.

The average waste to ore ratio for the entire mining operation is 0.6 to 1, though the actual ratio will fluctuate over the life of the project. Initially, the waste to ore ratio will be about 1 to 1, while towards the end of mine-life the ratio will be less than 0.2 to 1. In terms of ore processing, the requirements for stage 1 is 200 000 tpa. A two-fold increase in ore demand will occur in stage 2 (estimated to occur in years 3 and 4) and a four-fold increase of the initial ore requirements for stage 3 processing. Typical analyses of the ore and waste materials are given in Table 1.1 below:

Table 1.1 Typical Extractives Composition

Component	Meas. Unit	ROM Ore	Waste Magnesite	Overburden	Whites Formation
Al ₂ O ₃	%	0.37	1.6	13.0	6.5
SiO ₂	%	4.67	10	65.5	28
TiO ₂	%	0.04	0.2	1.2	0.4
Fe ₂ O ₃	%	1.16	2.5	10.5	2.9
MnO	%	0.22	0.2	0.3	0.5
CaO	%	0.38	3	0.2	13.5
K ₂ O	%	0.003	<0.1	1.8	0.3
MgO	%	44.6	37	1.2	21
P ₂ O ₅	%	0.01	<0.1	0.04	0.08
SO ₃	%	<0.01	<0.01	0.01	0.03
Na ₂ O	%	0.02	<0.1	0.05	0.08
LOI	%	48.5	45	6.0	26
Cu	Ppm	<2	<2	60	60
Pb	Ppm	<10	<10	40	20
Zn	Ppm	4	10	40	40
As	Ppm	<10	<10	20	15
Percentage of waste		NA	75	20	5

Note: LOI Lost on ignition: mainly water and carbon dioxide.

2. Crushing and Screening

After initial extraction and removal of waste rock, the ROM ore will be crushed in a two stage crushing circuit and screened to separate coarse (>6mm) material from the fines (<6mm). The coarse fraction (estimated to be about 80% of the ROM ore) will be sent to the calciner.

Fines will not be processed further and will be temporarily stockpiled near the crusher. It is expected that these fines will be saleable to the agricultural industry and material sold will be subsequently removed from site. Fines material not sold will be mixed with the slag and disposed of to the slag dump. There is no difference in chemical composition between the coarse and the fine fractions, both having the same composition as ROM ore (see Table 1.1).

3. Calcining

The separated coarse ROM ore will be roasted in the calcining kiln, to remove water and carbon dioxide. Attrition in the kiln is expected to produce a small amount of dust, which will be picked up in the off-gas stream and removed in a baghouse or an electrostatic precipitator. Again, it is expected that these fines will be saleable and will be temporarily stockpiled nearby. As outlined above, fines not sold will be mixed with slag and disposed of at the slag dump.

As a result of kiln malfunctions or startup and shutdown procedures, modest amounts of partly calcined material will occasionally be produced. Each batch of partly calcined material will be assessed and if suitable will be recycled through the kiln. Any batch considered unsuitable for recycling will be disposed of at the slag dump.

Periodically there will be a build-up of material deposited on the interior of the kiln. This material will occasionally break away and emerge from the kiln as irregular flat pieces of scale. These scale pieces will be screened out, cooled and disposed of to the slag dump.

Off-gas, generated from the decomposition of carbonate rock, and residue from combusted natural gases will pass to the bag house or electrostatic precipitator where it will be cooled, particulate matter removed, and vented to the atmosphere through a 63m high stack. See Table 1.2 below for composition of outputs.

Table 1.2 Typical Chemical Composition of Calciner Products

Component	Meas. Unit	Furnace Feed	Off-gas	Dust	Partly Calcined Material
Al ₂ O ₃	%	0.7	-	0.7	0.5
SiO ₂	%	9.0	-	9.0	6.8
TiO ₂	%	0.09	-	0.09	0.07
Fe ₂ O ₃	%	2.3	-	2.3	1.7
MnO	%	0.4	-	0.4	0.3
CaO	%	0.7	-	0.7	0.5
K ₂ O	%	0.01	-	0.01	<0.01
MgO	%	86.6	-	86.6	65
P ₂ O ₅	%	0.02	-	0.02	0.02
SO ₃	%	-	-	-	-
Na ₂ O	%	0.03	-	0.03	0.02
CO ₂	%	-	13.8	-	25
H ₂ O	%	-	11.2	-	-
N ₂	%	-	75	-	-

4. Furnace and Condenser

The calcined material is to be transferred hot (~900⁰C) to the furnace feed system where it will be mixed with the other reagents, and fed into the furnace. In the furnace the magnesium oxide will react with the reagents producing magnesium vapour and a residual slag which will be tapped periodically. Residual ferrosilicon that accumulates at the base of the slag will be segregated and stockpiled, as it is proposed to sell this material back to the ferrosilicon supplier. Aside from this the cooled slag will be crushed and thoroughly wetted with water in a well-ventilated location. At this point the slag will be mixed with any unsold fines and taken to the slag dump.

Magnesium vapour passes from the furnace into the condenser where it is converted to magnesium liquid, which accumulates at the base of the condenser. Crude magnesium is periodically tapped from the condenser. Any remaining uncondensed gases will pass out of the condenser and back to the kiln for combustion. These gases are predominantly magnesium vapour with small amounts of calcium, silicon and possibly sodium.

Over several days operation a small amount of residue will accumulate throughout the condenser. Approximately every three days the process will be shut down briefly and the condenser replaced. This residue will be cleaned out of the replaced condenser. Table 1.3 details the chemical composition of each output of this processing stage.

Table 1.3 Typical Chemical Components of Furnace-Condenser Products

Component	Meas. Unit	Crude Mg	Residual FeSi	Slag	Off-gas	Condenser Residue
Mg	%	86.5	-	-	97.3	12
Si	%	0.4	40	-	0.5	-
Ca	%	0.9	-	-	1.0	-
Other	%	0.13	1.8	4.0	0.15	-
MgO	%	9.6	-	52.0	-	70
SiO ₂	%	-	-	34.0	-	-
CaO	%	-	-	10.0	-	-
Fe	%	-	58.2	-	-	-
Ar	%	-	-	-	1.0	-
Mg ₃ N ₂	%	2.4	-	-	-	18

5. Refining and Calcining

The crude magnesium is refined by adding a flux consisting of magnesium chloride (40%) and potassium chloride (60%). Other fluxes used are ferric chloride, aluminum fluoride and calcium fluoride. The quantity used of these fluxes varies according to the quality of the crude metal produced. All fluxes with the exception of cover fluxes are added to the liquid crude magnesium as it is agitated. Calcium is precipitated as calcium chloride, while the ferric chloride reacts to produce metallic iron, which dissolves the silicon present and settles out. The magnesium oxide and magnesium nitride (Mg_3N_2) are wetted by the flux and settle out into the sludge. The refined magnesium is then poured into casting molds under a cover gas of sulphur dioxide (SO_2). Moisture contained in the flux used in the refining process produces a fume of hydrochloric acid (HCl). Sulphur dioxide is used as a cover gas to inhibit burning of magnesium. These are both sent to the acid scrubber. The sludge is retained for treatment. Table 1.4 summarises the chemical composition of the refining and calcining outputs.

Table 1.4 Typical Chemistry of Refining and Casting Products

Component	Meas. Units	Metal Product	Sludge	Fume
Mg	%	99.82	12.0	-
Si	%	0.01	1	-
Ca	%	-	-	-
Other	%	0.15	-	-
MgO	%	-	42.1	-
MgN ₂	%	-	7.1	-
MgCl ₂	%	-	4.8	-
KCl	%	-	11.9	-
AlF ₃	%	-	1.15	-
CaF ₂	%	-	2.3	-
CaCl ₂	%	-	5.6	-
Fe	%	-	12.1	-
HCl	%	-	-	98.4
SO ₂	%	0.02	-	1.6

6. Sludge Processing

The sludge produced in the refining process will be treated immediately by mixing with water, followed by a two-stage filtration process to recover magnesium metal and collect solids for disposal. The final liquid fraction is spray-dried to precipitate magnesium chloride and potassium chloride, which are used to reconstitute the flux for refining. The particulate matter for disposal is composed of calcium sulphate (gypsum), magnesium oxide, aluminum fluoride and calcium fluoride. Since these materials contain leachable salts, they will be sent to a certified waste disposal facility.

An ammonia fume is produced during processing as a result of the hydration of Mg_3N_2 . This ammonia is to be reacted with sulphuric acid to produce ammonium sulphate liquor, which will be sold. Fumes generated during the sludge processing will be sent to the acid scrubber. The chemical composition of all outputs in the sludge processing is given in Table 1.5.

Table 1.5 Typical Chemistry of Sludge Treatment Produced

Component	Meas. Unit	Recycle Metal	Solid Waste	Flux	Fume
Mg	%	99.8	-	-	-
MgO	%	-	70	-	-
CaF ₂	%	-	3.0	-	-
AlF ₃	%	-	1.5	-	-
CaSO ₄	%	-	8.8	-	-
Fe	%	-	15.6	-	-
Si	%	0.01	1.3	-	-
MgCl ₂	%	-	-	44	-
KCl	%	-	-	56	-
NH ₃	%	-	-	-	92.3
H ₂	%	-	-	-	7.7
Other	%	0.15	-	-	-

7. Condenser Residue Treatment

A small amount of residue will accumulate in the condenser over time, with the requiring replacement of the condenser approximately every three days. This residue will be cleaned out of the condenser and will consist of magnesium oxide, magnesium nitride and magnesium metal. The condenser residue is treated with a limited amount of water, and the subsequent hydration of magnesium nitride produces magnesium oxide and an ammonia fume. The ammonia fume is treated with sulphuric acid to produce ammonium sulphate liquor, which will be sold. The water will also react with the magnesium metal to produce magnesium oxide and a hydrogen fume, which will be sent to the acid scrubber, and any remaining magnesium oxide will be disposed of with the slag. Composition of the outputs in this stage of the process are given in Table 1.6 below.

Table 1.6 Output from Condenser Residue Treatment

Component	Meas. Unit	Solids	Fume
MgO	%	100	-
NH ₃	%	-	85.9
H ₂	%	-	14.1