99-4355

491001

BHP

MINERAL HOLDINGS AUSTRALIA PTY LTD

Silicon Carbide Plant Study

Rev B ***29/7/99***

AMG REFERENCE POINTS ADDED

BHP Engineering
BHP Service Companies

MINERAL HOLDINGS AUSTRALIA PTY LTD

Silicon Carbide Plant Study

Rev B ***29/7/99***

BHP Engineering
BHP Service Companies

Selwyn Street
P O Box 281 NEWCASTLE NSW 2300
Australia

Telephone (02) 49401 501
Fax (02) 49 401555

491003

Contents

1.0 Summary

BHP Engineering (BHPE) were engaged by Mineral Holdings Pty Ltd (MHA) to amend a silicon carbide (SiC) plant prefeasibility study report produced for Green Consultants Pty Ltd in 1998. The amended study report reflects changes in the world market outlook for high quality SiC since completion of the previous study, along with new information regarding the silica feed-stock resource for a proposed SiC plant located in south-eastern Australia.

Following a review of the supplementary data and market prospects provided by MHA between 16th July 1999 and 21st July 1999, BHPE have revised the original capital and operating costs for a SiC production facility. While still basing the flowsheet & equipment list on Electroschmeltzwerk Kempten (ESK) technology, **BHPE have revised the production capacity proposed for the SiC plant from 45,000** tpa to **15,000 tpa based on Australian and overseas markets and existing global production capacity.** As future demand dictates, the plant could be increased in capacity in a modular fashion in increments of 15,000 tpa -taking advantage of the economy of scale afforded by larger plant capacity.

Two potential plant locations have been considered in the revised study:

1. Situated at Bell Bay near Georgetown on the north-eastern coast of Tasmania - making use of established infrastructure and a skilled workforce. The gas supply for this plant would be via LPG deliveries to an on-site gas storage facility or Natural Gas via a proposed pipeline from Victoria to Bell Bay.

2. Situated in the Latrobe Valley, Victoria - making use of proximity to established infrastructure and a lower electricity supply cost. The gas supply for this plant would be via connection to the existing natural gas distribution piping network.

Main raw materials would be sourced as follows –

- 23,000 tpa silica sand (99.8% SiO_2) from Mount Thomas, transported by road (to Bell Bay) or by rail & ship (to Victoria).

- 7,500 tpa petroleum coke from USA, delivered by ship.,

- 3,000 tpa anthracite imported from Vietnam, by ship.

- 12,000 tpa dry timber (25% moisture) & 2,200 tpa sawdust from timber mills, transported by road.

- 200 tpa graphite electrodes from Japan, delivered by ship.

Tight control of raw material quality and product handling will maximise production of premium grade "green" SiC.

The plant would generate up to 13% of its total electrical power requirements on site from furnace off-gases via an energy recovery unit (ERU).

The capital cost of the plant is estimated at AUS$155 Million (+/-50%) with the potential to reduce this cost to AUS$140 Million by locating the plant adjacent to a power station and negotiating power price based on the utility provider installing the gas-handling and water treatment equipment required.

The plant would have an estimated operating cost of AUS$1109/tonne. This operating cost may be reduced to AUS$1077/tonne if the full electricity-generating potential of the furnace off-gases is realised.

Average sale price for SiC product from the proposed plant would need to be AUS$1365/tonne or less to compete with cheap imports from China and Brazil.

With the product mix assumed, and based on current average import prices, the proposed plant would obtain an average sale price of AUS$1406/tonne for its product.

2.0 Silicon Carbide Production

Silicon carbide (SiC) can be produced by a number of different methods, but by far the predominant commercial process for its production is by thermal reduction of silica sand and carbon in an electric resistance furnace.

The overall reaction proceeds according to:

$$SiO_{2(s)} + 3\,C_{(s)} \rightarrow SiC_{(s)} + 2CO_{(g)} \uparrow$$

The reaction proceeds in the temperature range 1700°C - 2500°C in the following stages:

$SiO_{2(s)} + C_{(s)} \rightarrow SiO_{(s)} + CO_{(g)} \uparrow$ starts as SiO_2 melts at 1700°C,

$SiO_{(s)} + C_{(s)} \rightarrow Si_{(s)} + CO_{(g)} \uparrow$

$Si_{(s)} + C_{(s)} \rightarrow SiC_{(s)}$ with the SiC forming as a crust on the carbon grains, eventually causing the reaction to cease.

β-SiC crystals (90% SiC) form first (between 1700 -2100°C) and conversion to the purer α-SiC crystals (>98% SiC) occurs between 2100-2500°C.

Heating above 2500°C will lead to decomposition to silicon and graphite.

The two main processes which produce SiC via this reaction are the **Acheson process** and the **ESK process**. The ESK process is a modification of the Acheson process equipment to allow capture and treatment of the furnace off-gases.

Other Production Methods

SiC can also be produced from feedstocks other than SiO_2 and carbon. However, these methods only produce β-SiC powders (which are not suitable for most applications of SiC) and have high operating costs:

- Plasma jet decomposition of gaseous mixture of CH_4, $SiCl_4$, $C_2H_6Cl_2Si$ and CH_3Cl_3Si.
- Plasma jet decomposition of gaseous mixture of C_3H_8, SiH_4, H_2, HCl.
- Thermal decomposition of rice husks (low yield ~10%).

2.1 ESK Process

The ESK process has been selected as the basis for the production plant in this study for three main reasons:

(i) It represents the most modern commercially proven technology for large-scale production of SiC,

(ii) It represents the most efficient and environmentally-friendly commercial method of production currently available.

(iii) It maximises production of high purity α-SiC crystals (which are required for abrasives manufacture) by use of large furnaces.

A typical flowsheet for the ESK process is shown in **Figure 1**.

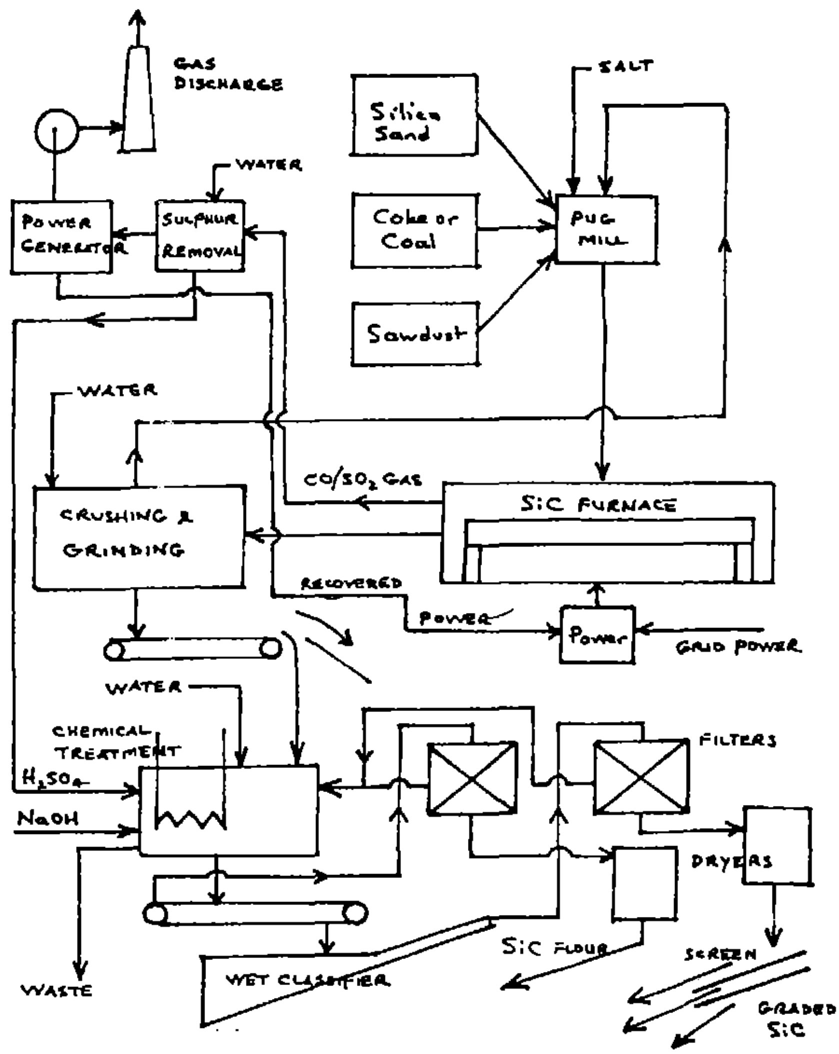
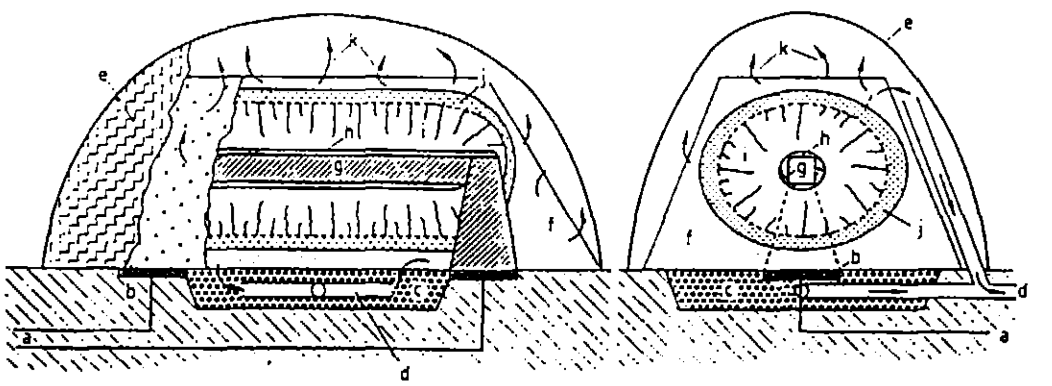


Figure 1: ESK process flowsheet

The furnace used in the ESK process is shown schematically in **Figure 2**. Typically, in the larger production units, the heating core is 60 m long and the furnace mound is 6 m high. Approximately 3000 tonnes of feed material is charged to such a furnace.



ESK furnace
a) Electrical supply; b) Floor electrode; c) Gas-permeable furnace bed; d) Gas collection; e) Plastic sheet; f) Reaction mixture; g) Heating resistor (core); h) Graphite from decomposition of SiC; i) Silicon carbide: coarsely crystalline inner zone; j) Silicone carbide: finely crystalline outer zone ("amorphous"); k) Furnace gases

Figure 2: Typical section of ESK SiC Furnace

A graphite column is placed in position on top of each of the two floor-mounted electrodes. Raw materials (a -10mm mixture of silica sand and either petroleum coke or low-ash coal, plus sawdust to help liberate the CO gas produced) are charged to the furnace bed by wheel loaders until the pile reaches the top of the graphite electrode columns. The heating core (either linear or U-shaped) is then positioned between the columns and covered with the remainder of the furnace charge.

The furnace mound is then covered with a plastic (polyethylene) sheet which traps the furnace gases evolved during reaction, causing the sheet to inflate thus protecting it from the heat. The gas removal rate is controlled to maintain a constant pressure in the furnace.

The furnace power (usually AC) is switched on at an initial voltage of 230 V and current of 6000 A. As the reaction proceeds over the next 8 - 10 days, the voltage decreases to 75 V and the current increases to 20,000 A.

Following completion of the reaction, the furnace is cooled over several days and then the gas collection sheet is removed to allow access for removal and separation of the inner core (reacted material) and un-reacted outer material.

2.2 Raw Materials

The purity of raw materials is critical to the production of high quality, maximum sale price SiC.

Silica Sand:

Very high grade silica sand is essential (>99.0% SiO_2, preferably >99.7% SiO_2) with very low traces of Fe_2O_3 (0.01-0.05%) and Al_2O_3 (0.02-0.5%). Preferred sizing is -2 mm to -6 mm.

To produce **green SiC**, require silica sand with **< 0.05% Al_2O_3**.

To produce **black SiC**, require silica sand with **0.05-0.15% Al_2O_3**.

The proposed feed-stock for the Australian SiC facility is of very high purity (>99.8% SiO_2, <0.012% Fe_2O_3, <0.03% Al_2O_3) and a significant test sample (150t) has been successfully converted to high grade SiC during trials with a major world producer (Norton AS Lillesand, Norway facility). **This sample was unwashed (by error) but still produced excellent quality SiC - apparently exceeding that obtained from usual Norton silica feedstock[1].**

The full analysis of the NW Tasmanian silica source is presented in Appendix A.

Carbon:

The feed carbon to the furnace is a graded mixture of low ash, low sulphur petroleum coke (<3 mm), screened low ash anthracite (< 6 mm), and small charcoal (2-20 mm). The correct size distribution is critical to ensure sufficient carbon reactivity to produce SiC in the minimum time and at maximum % conversion.

Low sulphur (< 0.3%) is preferred to minimise production of H_2S & SO_2 in the off-gases, which require scrubbing before discharge. However, if gas stream sulphur can be recovered as elemental S (for sale) then higher levels of sulphur (up to 1.5%) can be tolerated.

High quality petroleum coke (94% C) as used in the manufacture of anodes in the Australian aluminium industry is imported from companies such as Reynolds and Arco, at US$250-300/tonne. **No suitable coke is produced within Australia.**

Low ash anthracite (85% C) is available from Vietnam for US$80/tonne. **No suitable anthracite is currently produced within Australia.**

Charcoal (92% C) can be produced from timber for approximately AUS$100/tonne. This would be produced on site in retorts.

Graphite:

Electrode quality graphite is required to form the columns and heating core in each furnace. Provided care is taken in charging and discharging the furnaces, the consumption of electrode material should be very low - covering breakages and minor reaction losses ($C_{(s)} + CO_{2(g)} \rightarrow 2CO_{(g)}\uparrow$). **Graphite electrodes would be imported for the proposed plant.**

Sawdust

Green sawdust is required at a rate of about 4% of the feed mix, in order to render the charge mass porous during the reaction period, enabling CO and other reaction gases to escape without causing rupturing of the charge mass and damage to the heating core, columns and floor structure. **Sawdust would be sourced locally.**

Salt

Sodium chloride is sometimes added to the charge mixture to allow removal of impurities in the silica sand as volatile chlorides (in the off-gases). If used, it constitutes approximately 1% of the charge. **Salt would be obtained from domestic producers (eg Cheetham salt, Geelong, Victoria).**

2.3 Power Consumption

The reaction between SiO_2 and C to produce SiC is highly endothermic, requiring a theoretical energy input of 4.7 MWh/t SiC. However, due to thermal and electrical inefficiencies, the actual power input required is in the range 7-10 MWh/t SiC.

To achieve economy of scale and higher electrical efficiency, modern ESK furnaces are very large (up to 60 m long) and are powered by up to 15 MVA (12 MW) transformers. Typical power input is 8-9 MW.

To maintain a symmetrical load on the incoming plant power supply, these furnaces are often connected in sets of four off a single 60 MVA (48 MW) transformer.

The voltage and current to each furnace is varied as the reaction proceeds, from 230 V and 6,000 A to 75 V and 20,000 A.

2.4 Product Uses

There are several major applications for SiC, dependent on material composition and grain size:

1) **Abrasives** - SiC has a hardness of 9.5-9.75 Moh. Typically green or black, with >98% SiC (minor constituents 0.5% Si, 0.1% C, 0.3% SiO_2, 0.01% Al_2O_3) it is used in the abrasives industry.

2) **Refractories** - SiC has a high resistance to oxidation, high thermal conductivity and low coefficient of thermal expansion, making it ideal for use in refractories production. Kiln furniture is usually made from 70% coarse (100 μm) and 30% fine (< 10 μm) SiC.

3) **Metallurgical additions** - low purity SiC is used as a silicon source in the production of silicon-bearing alloys and as a de-oxidising agent in steel production, with annual world consumption at **approximately 280,000 tpa**. Typically -10mm grain size and 90% SiC (minor constituents 4% SiO_2, 1.1% Si, 2% C). **A new application which could become a major consumer of SiC world-wide is in alloying with aluminium to produce Duralcan™ (Alcan) for use in automobile brake components.**

4) **Electrical technology** - high purity SiC bonded by Si infiltration is used to produce rods and tubes for heating elements in resistance furnaces. SiC powder is also used as an insulation filler for high-voltage cables.

5) **Electronics** - high purity SiC crystals and "whiskers" produced by vapour phase sublimation are used for producing semiconductors in the electronics industry.

6) **Structural ceramics** - sintered high purity SiC powders are used to manufacture such structural components as wear

rings and seals for pumps, ball valve seats, sliding bearings and shaft housings.

2.5 By-products & Wastes

The main by-products and wastes from SiC production are:

1) **Sulphur** - recovered from the predominantly CO furnace off-gases in a desulphurisation unit.

2) **Graphite** - some of the raw mix carbon immediately adjacent to the heating core is converted to graphite due to the extremely high temperatures (partial decomposition of inner SiC core to Si and C).

3) **Chemical treatment sludge** - the impurities (mainly Fe_2O_3 and Al_2O_3) removed from the SiC product by acid and alkali washing.

4) **Abrasion residue** - a mixture of steel, scale and fine SiC dust removed from the ground SiC by magnetic separation.

5) **Scrubber residue** - acidic sludge from fluid bed dryers' vapour scrubbers.

6) **Waste-water** - aqueous discharges from product washing, filtration and chemical treatment.

3.0 Previous Studies

3.1 BHPE Study (Report 13190 Rev C 17/7/98)

In June 1998 BHP Engineering were approached by Green Consultants Pty Ltd to prepare a pre-feasibility study for a Silicon Carbide plant to be located in northern Tasmania. Unfortunately, no information regarding the proposed silica source, intended plant capacity or expected markets for the product was supplied to BHPE for this study.

BHPE therefore made certain assumptions which led to the estimation of capital and operating costs for a 45,000 tpa plant producing 3,000 tpa green SiC, based on ESK technology. Due to suspension of the study prematurely by the client, and considering the lack of detailed information forthcoming from existing SiC producers upon which to base costs, the estimates provided in the 1998 study are only considered "order of magnitude" (ie +/- 50%).

3.2 Fluor Daniel Study (Report April 1988)

MHA Pty Ltd provided a copy of a 1988 Fluor Daniel report entitled "Review of Synthetic Abrasive Production for Victoria". In this report, Fluor Daniel provide capital cost and operating cost estimates (accuracy not stated) for conventional and new technology processing routes to produce 15,000 tpa SiC. A financial analysis was also provided showing the net cash flow for the project over the first five years of operation.

The economic data from the Fluor Daniel report has been used in conjunction with other confidential information provided by MHA (refer to Appendices C & D), to check the original BHPE estimate accuracy, and modify these capital and operating cost estimates to reflect the change from a 45,000 tpa plant capacity to 15,000 tpa.

4.0 World Production

4.1 Overall Market

The current world SiC production capacity is estimated at **1,100,000 tpa**[2], of which:

- 41% is from China,
- 24% is from Western Europe,
- 21% is from North & South America, and
- 14% is from Eastern Europe.

Amongst the largest capacity plants are:

- ESK plant at Delfzijl, Holland; 60,000 tpa.
- Exolon-ESK plant at Hennepin, Illinois, USA; 45,000 tpa (soon to upgrade to 56,000 tpa),
- Casil SA plant at Barbacena, Brasil; 45,000 tpa,

Demand for SiC is estimated at only **800,000 tpa**. However, supply and demand world-wide are currently in balance due to the following factors:

- Few suppliers are operating at full plant capacity due to energy costs.
- Environmental constraints on many producers who directly emit production off-gases to the atmosphere (coke and sulphur emissions).

Approximately 45% of world production is metallurgical grade (85-90% SiC), 35% is abrasives grade (>97%) and the remainder is refractories and electrical applications. A new emerging market for SiC is for alloying to aluminium for use in disc brakes in the car industry (eg Duralcan™ - being developed by Alcan).

It is anticipated that there may be a reduction in Chinese output or at least an increase in Chinese SiC prices during the next 12 - 18 months as a result of expected increases in power costs within China. **However, market analysts have been predicting this scenario since the early 1980s, and therefore BHPE believe that this development alone should not form the basis**

of any market penetration strategies for a proposed new SiC plant.

In terms of the Australian market[3] for SiC, the current consumption is between 4800 - 5000 tpa consisting of -

- 3000 tpa refractories grade,
- 1250 tpa metallurgical grade, and
- 550 - 750 tpa abrasives grade SiC.

4.2 Key Producers

There are currently two major players amongst the world's SiC producers -

- Norton Saint-Gobain.
- Wacker-Chemie (ESK & Exolon-ESK).

The major SiC production facilities (excluding China) are:

Company	Plant	Production (tpa)	Products
Norton Saint Gobain	France		
ESK GmbH	Delfzijl, Holland	60,000	Abr, refr.
Arendal Smeltverk AS	Norway	42,000	Abr, refr, met.
Norton AS	Lillesand, Norway	25,000	
Orkla Exolon AS	Norway	15,000	
Lonza G+T AG	Switzerland		
Sicven	Venezeula	27,000	Abr, refr, met.
Casil SA	Brazil	45,000	Abr, refr, met.
Exolon-ESK	Illinois, USA	45,000	Abr, refr, met.
Norton Saint-Gobain	Shawinigan, Quebec, Canada		
Washington Mills Co	Niagra Falls, USA		

3.3 Prices for High Quality Product

The average sale price per tonne for all grades of SiC is US$570/t (ie AUS$877/t).

Typically, high purity SiC powder is sold for the highest price of all SiC products. Finely ground product for use in electronics applications is sold for very high prices; for example 99.9% SiC powder with < 100 μm particle size sells for approximately US$24/kg.

Average prices (1988) for various grades of SiC sold in bulk quantities are as follows:

8.22 mesh CIF European port -

• Green SiC (>99.5%)	US$1598/t (AUS$2458/t).
• Black SiC (99%)	US$1287/t (AUS$1980/t).
• Grey SiC (90%)	US$410/t (AUS$630/t).

Approximate current prices[4] for SiC imported into Australia are:

• Abrasives grade ("green")	AUS$2200/t.
• Refractories grade ("black")	AUS$1800/t.
• Metallurgical grade ("grey")	AUS$900/t.

5.0 Proposed Plant

5.1 Potential Site Locations

The silica sand deposit is at Mount Thomas (refer to map in Appendix A) on the north-west coast of Tasmania.

A suitable processing site will need access to cheap power, a skilled work-force, timber & sawdust (as raw materials) and an industrial port for receiving imported raw materials (eg graphite) and exporting finished product. It would be preferable to locate the plant in a sparsely populated area, due to fugitive silica and coke dust emissions.

Option A - Tasmania

A site located at Bell Bay (near Georgetown) is considered suitable due to the following features:

- Ferrosilicon industry long established at TEMCo (ie skilled work-force and local contractors familiar with similar industry).

- There may be opportunity to economise on import of raw materials (eg coke, graphite) via shipments already handled in port (for TEMCo & Comalco).

- Gunns Ltd operate many near-by timber mills producing sufficient timber & sawdust to meet SiC production requirements.

- 290 MW power station and associated infrastructure existing.

- No major population centres adjacent.

Option B - Victoria

A site located in the Latrobe Valley adjacent to one of the large power stations is considered a viable alternative to (A) due to the following features:

- Cheaper 20 year power contracts available in Victoria compared with Tasmania (ie $35/MWh compared with $40/MWh).

- Established infrastructure for natural gas piped to plant.

A site area of approximately 15 hectares will be required for the SiC plant, based on the site lay-out of the ESK SiC plant at Delfzijl, Holland.

5.2 Preliminary Process Flow-sheet

The preliminary process flow-sheet is shown in drawing 16086/001 Rev B attached, along with the mass and energy balance in Appendix B. The mass balance has been based on an average feed mix composition drawn from data in a number of sources (see reference list in Section 8.0). It has been assumed that propane gas (LPG) will be available as the fuel gas for charcoal production in Tasmania, or natural gas in Victoria.

5.3 Preliminary Equipment List

An equipment list (Appendix C) has been developed based on the preliminary flow-sheet and information provided by various equipment suppliers to the SiC and related industries. Minor equipment items not associated directly with the production stream (eg water treatment plant and general utilities) have been sized based on studies for a similar scale ferro-alloy plant.

5.4 Plant Capacity & Product Mix

The plant capacity has been selected as 15,000 tpa total SiC product, based on servicing the domestic market (approximately 5,000 tpa) plus targeting the South-East Asian market (including Japan - which consumes approximately 55,000 tpa). Australia currently imports SiC mainly from Brazil, while the Japanese buy their SiC from cheap Chinese producers. However, with power prices in China set to increase dramatically in the next 12 - 18 months (by two to three times!), the door is open for a cheaper high quality producer to take over this market. Large plants (45,000 - 60,000 tpa) enjoy economy of scale, however require a cheap source of power from a utility capable of sustaining a relatively large base load.

A plant based on a 15,000 tpa production "module" could be expanded in future as the market demands by adding additional 15,000 tpa production modules (to bring capacity up to say 45,000 or 60,000 tpa which would match the world's largest existing producers) .

The 15,000 tpa product has been divided into the following product mix:

- 1,000 tpa green SiC (99.5% purity) for abrasives manufacture,
- 7,000 tpa black SiC (99.0% purity) for abrasives and/or refractory manufacture,
- 7,000 tpa metallurgical grade ("grey") SiC (90% purity).

The split between high grade and met grade SiC is based on typical conversions to α-SiC and β-SiC reported in the literature, and reflects the current world production mix. The proportion of green SiC is based on reported production for the Casil SA Brazilian plant.

Maximizing green SiC production is dependent on high quality silica sand and carbon combined with stringent chemical treatment, filtration and washing quality control. Therefore, > 1,000 tpa green SiC production may be possible by selectively mining the Mount Thomas deposit and washing the feed material prior to furnacing.

5.5 Production Furnaces

15,000 tpa SiC can be produced by operation of eight (8) ESK furnaces, each with the following dimensions:

- 6 m wide x 40 m long, heating core length - 30 m.

The furnaces are arranged in two (2) banks of four (4), with each bank connected to a single 60 MVA transformer.

Furnace raw gases are collected and ducted underground to the Energy Recovery Unit (ERU) after desulphurisation.

5.6 Feed Preparation

Raw materials (petroleum coke, anthracite, charcoal, silica sand, sawdust, salt and recycled furnace mix) are weighed and blended in pug mills prior to batching into the furnaces via front end loaders. Recycled mix must be broken down to -10mm before blending with fresh mix materials. This size reduction is achieved in the product crushing & grinding plant (refer to Section 5.7.1).

5.7 Product Handling

Initial break-up and removal of the reaction mixture is by use of hydraulic breakers "in-situ" at the furnace, following water spraying of the reaction mixture over a 4 day "cool-down" period. Large lump material is then carried by front-end loaders to the jaw crusher feed bin grizzlies for further break-up by pneumatic hammers prior to primary crushing.

5.7.1 Crushing & Grinding

Choice of crushing equipment depends on the desired product grain size and shape. For the purposes of this study it has been assumed that:

- Grit sizes for abrasives grade SiC will be -2mm and meet FEPA standards,
- Powder size for refractories grade SiC will be 70% -100 µm and 30% -10 µm,
- Metallurgical grade SiC will be -10mm + 2mm.

Two (2) Metquip jaw crushers are used to crush the primary lumps removed from the furnace by hydraulic breakers and pneumatic hammers from lump size (-100mm) to grinding mill feed size (-10mm). Each crusher has a capacity of 20tph.

Two (2) Humboldt Wedag hammer mills are used to reduce the -10mm SiC to the various product sizes (-2 mm for high grade, +2 mm for met grade). A proportion of this crushed material is recycled to the feed preparation plant for blending with fresh feed mix. Each mill has a capacity of 20 tph.

Two (2) Alpine fluidised bed opposed jet mills are used to fine grind the refractory grade SiC from -2mm to -100 µm powder. Each jet mill has a capacity of 5 tph.

5.7.2 Chemical Treatment

Due to its highly inert nature, SiC is essentially un-reactive towards concentrated sulphuric acid or caustic soda. Therefore, hot solutions of these reagents are used to remove the following trace impurities from the SiC required for abrasives and refractory applications:

- Elemental Si and SiO_2,
- Graphite,
- Iron and aluminium oxides,

- Metals (from grinding circuit and furnace).

The ground SiC is mixed in agitated tanks with hot sulphuric acid (30%) at 70-80°C for 1-2 hours to remove the trace impurities into solution. The solution is then neutralised with hot caustic (50% NaOH) at 70-80°C prior to filtration and washing to separate the pure SiC grains from the waste liquor.

5.7.4 Filtration & Washing

Filtration is carried out on two (2) Delkor horizontal vacuum belt filters with a capacity of 20 tph dry solids each.

Residual acid, alkali and contaminants are removed by water washing of the filtered solids.

5.7.5 Drying

Low temperature indirect drying by steam in a fluidised bed removes residual wash water from the SiC without oxidation to SiO_2. As SiC oxidation only commences at 600°C, product quality remains high in this unit operation.

Exhaust gases from the dryer contain SiC dust and acidic vapours, and are wet scrubbed prior to discharge to atmosphere.

5.7.6 Product Classification

Classification of dried high grade material is carried out by cyclones, air classifiers and elutriators prior to packaging for despatch. Products intended for the abrasives market must be tested to ensure they meet the AGA (American) or FEPA (European) standards for abrasive grain products.

5.8 Gas Handling & By-Products

The ESK furnace gas collection system directs cooled furnace off-gases ($CO/CO_2/H_2S$/chlorides) to a desulphurisation unit (eg an ARI Lo-Cat II unit) for removal of sulphur compounds as elemental sulphur, prior to combustion in a boiler to generate steam for a turbine which produces on-site electricity. Some of the raw gas is diverted to a flare stack upstream of the ERU, to provide pressure control during fluctuations in the rate of off-gas generation from the furnaces. The off-gas control system is shown schematically in **Figure 3**.

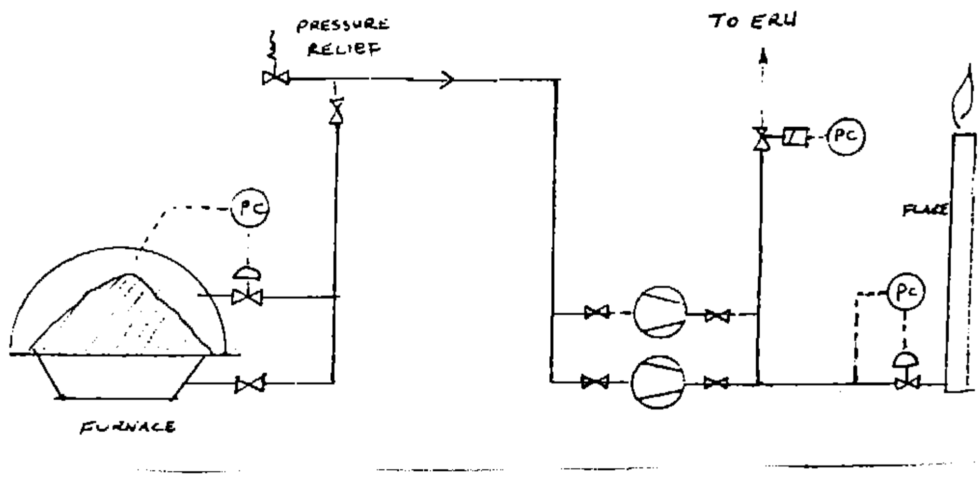


Figure 3: Furnace Gas Control System Schematic

5.9 Reagents & Utilities

The following chemical reagents are utilised in the SiC production process:

- Sodium chloride (NaCl) as a flux for impurities removal - 550tpa .

- 64 tpa sulphuric acid (98%), and 26 tpa caustic soda (50% NaOH) for chemical treatment of high grade product, and for resin regeneration in the ERU boiler feedwater plant.

- Process water for steam generation, charcoal retorts, chemical treatment and filter washing - 600,000 m^3/year (approx. 75 m^3/h).

- Filter aid for filtration units.

- Flocculants and water treatment chemicals (biocides, scale inhibitors, dispersants etc) for water treatment plant.

- Ion exchange resins, activated carbon & amine for boiler feedwater plant.

Charcoal

High purity carbon is generated on-site by production of charcoal from dry timber, and the charcoal retorts require the following:

- 12,000 tpa timber (up to 25% moisture content) as feed,
- 50,000 m^3/year of LPG as fuel for timber drying.
- 6,000 m^3/year of demineralised water.

Electrical Power

Electricity consumption has been assumed as 9 MWh/t of SiC. Evidence from some existing producers suggests 7 MWh/t of SiC is achievable, however for the purposes of this report the higher consumption figure has been used. This results in a plant power usage of 21 MW.

However, approximately 13% of the production power requirements can be met by recovery of power from the furnace off-gases via the ERU. This recoverable portion of power may increase to 25% depending on the efficiency of furnace off-gas capture, treatment and energy recovery.

Other major equipment drives (feed preparation, gas plant and product crushing & grinding) utilise around 0.7 MW, bringing the total site usage to 22 MW.

6.0 Capital Cost Summary

Details of the order-of-magnitude estimate (+/-50%) which has been prepared based on the limited equipment suppliers' information received to date, are presented in Appendix D.

In summary, the estimated capital cost for a 15,000 tpa SiC plant is AUS$155 Million (+/-50%). This cost includes:

- Feed preparation plant including charcoal plant - $12 Million.
- Production furnaces, associated transformers & switch-gear - $35.4 Million.
- Gas handling plant including desulphurisation unit & ERU - $12.7 Million.
- Product crushing & grinding plant - $35 Million.
- Chemical treatment plant - $2.7 Million.
- Product Finishing plant - $5 Million.
- Water Treatment Plant - $2.6 Million.
- Services - $0.3 Million.
- Infrastructure - $11.6 Million.
- EPCM - $11.7 Million.
- Start-up (EIS, training, ramp-up) & contingency - $25.8 Million.

Assessment of Estimate Credibility

The BHPE capital cost compares favourably with that based on the 1988 Fluor Daniel study (AUS$129 Million when adjusted to 1999 prices). However, the BHPE capital estimate appears too high compared with 1999 capital cost quoted to MHA by "a confidential industry source".

This source quoted US$56 Million (AUS$86 Million) for a 20,000 tpa facility. The accuracy of this estimate is unknown. This AUS$86 Million excludes any energy recovery or off-gas desulphurisation equipment. The BHPE estimate of AUS$155 Million would be revised to approximately AUS$142 Million without these items, however the project would not get approval in Australia without environmental safe-guards.

BHPE consider that if the furnacing plant cost in the estimate produced by MHA's "confidential industry source" covers the same equipment as listed under "Feed Preparation + Furnaces" in our equipment list, then the capital costs for this section of plant agree reasonably well.

However, it is impossible to make a fair comparison of our estimate accuracy against this industry expert's estimate without the following information regarding MHA's "confidential source":

- Confirmed plant capacity.
- Confirmed process flowsheet.
- Confirmed equipment list.

BHPE would appreciate the opportunity to re-assess this study's estimates if this information becomes available.

7.0 Operating Cost Summary

The estimated operating costs with and without energy recovery are presented in detail in Appendix E. In summary, the variable operating costs are:

1. AUS$1109/t SiC in Victoria, AUS$1110/t SiC in Tasmania with energy recovery,

2. AUS$1147/t SiC in Victoria, AUS$1154/t SiC in Tasmania without energy recovery.

These costs compare favourably with the rough "rule of thumb" that operating costs for SiC are 75% of sales revenue (based on this rule the operating cost would be AUS$1024/t based on the predicted product mix from the proposed plant).

The major components of the operating cost are electricity, labour and petroleum coke price.

An electricity price of AUS$35 - 40/MWh has been used based on pricing received during recent negotiations with both Victorian and Tasmanian utility providers for a magnesium smelter (to consume approx. 90 MW). This compares reasonably with the quoted MHA source price of US$18/MWh (AUS$28/MWh).

There is some evidence that a greater proportion of plant off-gas energy may be recoverable (up to 25% instead of the assumed 13%). This would reduce operating costs to AUS$1077/t.

As a major raw material subject to the US$/AUS$ exchange rate, the petroleum coke source is a critical factor in determining plant feasibility.

8.0 References

1.Letter from K.A.Stole, Norton Saint-Gobain to Neil Thomas, MHA dated 28/10/98.

2.Industrial Minerals, July 1999 issue - page 7.

3. Telecon with Keith Bettles, Wacker Chemicals Australia, 26/7/99.

4. Ibid.

5.Ullmann's Encyclopaedia of Industrial Chemistry, Vol A23.

6.Kirk & Othmer's Encyclopaedia of Chemical Technology

7.Mantell "Industrial Electrochemistry", McGraw-Hill.

8.Internet - http://www.casil.com

9."Comprehensive Inorganic Chemistry" Vol.1, Pergamon Press

10.Internet - http://minerals.er.usgs.gov/minerals/pubs/mcs/1996/manuabra.txt

11.Internet - http://www.ceramics.com/electro/green.html

12.Internet - http://www.nortonsic.com/products/.

13.Internet - http://www.exolonesk.com/news/century_silocn.html

14."Industrial Minerals Directory" 1991, p535.

9.0 Appendices

Appendix A

APPENDIX A -

491031 SILICAS SAND

MINERAL HOLDINGS AUSTRALIA ~~PTY.~~ LIMITED

A.C.N. 004 759 853

CERTIFICATE OF ANALYSIS

PRODUCT: **THOMAS MOUNTAIN SILICA SAND**
(Raw Material Unprocessed Pit 2)

PARTICLE SIZE:

+1180 µm	0.03%
-1180 +850 µm	0.35%
-850 +600 µm	4.85%
-600 +425 µm	21.48%
-425 +300 µm	29.25%
-300+212 µm	17.91%
-212+150 µm	14.49%
-150 +106 µm	7.31%
-106 +75 µm	3.04%
-75 +53 µm	1.18%
-53 µm	0.12%
TOTAL	100.00%

CHEMICAL ANALYSIS: SiO_2 greater than 99.8%

Fe_2O_3	113 ppm	0.0113%
TiO_2	570 ppm	0.0570%
Al_2O_3	287 ppm	0.0287%
CaO	31 ppm	0.0031%
MgO	23 ppm	0.0023%
Na_2O	19 ppm	0.0019%
Cl	120 ppm	0.0120%
CoO	<0.2 ppm	0.0002%
Cr_2O_3	<10 ppm	0.0010%
K_2O	59 ppm	0.0059%
V_2O_5	<2 ppm	0.0002%
ZrO_2	52 ppm	0.0052%
NiO	<2 ppm	0.0002%
WO_3	0.1 ppm	0.00001%

AMMTEC LTD REPORT # A4281 AUGUST, 1994

F I INDEX

491032

MINERAL HOLDINGS AUSTRALIA PTY. LIMITED

A.C.N. 004 759 853

Correspondence to:
2nd Floor,
135 COLLINS STREET,
MELBOURNE, VIC., AUSTRALIA 3000
TELEPHONE: (61 3) 654 7999
FAX: (61 3) 650 3855

CERTIFICATE OF ANALYSIS

PRODUCT: **CHAMPION ROAD SILICA FLOUR**
(Raw Material Unprocessed)

Typical assay sheet

PARTICLE SIZE:

+425 µm	12.6%
-425 +300 µm	2.4%
-300 +250 µm	1.3%
-250 +212 µm	0.9%
-212 +150 µm	2.9%
-150 +105 µm	4.3%
-106 + 75 µm	7.4%
-75 + 45 µm	21.8%
- 45 µm	46.4%

CHEMICAL ANALYSIS: SiO_2 greater than 99.7%

Fe_2O_3	35 ppm	0.0035%
TiO_2	101 ppm	0.0101%
Al_2O_3	237 ppm	0.0237%
CaO	870 ppm	0.0870%
MgO	870 ppm	0.0870%
Na_2O	22 ppm	0.0022%
Mn	0.5 ppm	0.00005%
Cu	0.2 ppm	0.00002%
Cr H.F.	0.2 ppm	0.00002%
Cr Alk Sln		
Ni	0.2 ppm	0.00002%

O

491033

MINERAL HOLDINGS AUSTRALIA PTY. LIMITED

A.C.N. 004 759 853

Correspondence to:
2nd Floor,
135 COLLINS STREET,
MELBOURNE, VIC., AUSTRALIA 3000
TELEPHONE: (61 3) 654 7999
FAX: (61 3) 650 3855

CERTIFICATE OF ANALYSIS

PRODUCT: **CHAMPION ROAD SILICA FLOUR**
(Raw Material Unprocessed)

Typical assay sheet

PARTICLE SIZE:

+425 µm	12.6%
-425 +300 µm	2.4%
-300 +250 µm	1.3%
-250 +212 µm	0.9%
-212 +150 µm	2.9%
-150 +105 µm	4.3%
-106 + 75 µm	7.4%
-75 + 45 µm	21.8%
- 45 µm	46.4%

CHEMICAL ANALYSIS: SiO_2 greater than 99.7%

Fe_2O_3	35 ppm	0.0035%
TiO_2	101 ppm	0.0101%
Al_2O_3	237 ppm	0.0237%
CaO	870 ppm	0.0870%
MgO	870 ppm	0.0870%
Na_2O	22 ppm	0.0022%
Mn	0.5 ppm	0.00005%
Cu	0.2 ppm	0.00002%
Cr H.F.	0.2 ppm	0.00002%
Cr Alk Sln		
Ni	0.2 ppm	0.00002%

ICP TESTING BY DOW CORNING - 23.2.1994
(A. ARVIDSON)

THOMAS MOUNTAIN QUARTZITE EL.25/88

	A (Rock)	B (Rock)	C (Rock)	SAND
	%	%	%	%
$As_{2}0_{3}$	0.0008	0.0009	0.0013	0.0009
$Ba0_{2}$	0.0002	0.0002	0.0001	0.0001
$BI_{2}0_{3}$	0.0004	0.0003	0.0004	<0.0001
Cd0	0.0001	<0.0001	<0.0001	0.0001
Co0	0.0191	0.0173	0.0292	0.0234
$Cr_{2}0_{3}$	0.0001	0.0003	0.0004	0.0003
Cu0	0.0001	0.0001	<0.0001	0.0001
$La_{2}0_{3}$	0.0001	0.0001	0.0001	<0.0001
Mg0	0.0025	0.0030	0.0018	0.0027
Mn0	0.0003	0.0003	0.0001	0.0001
$Mo0_{3}$	<0.0001	<0.0001	<0.0001	<0.0001
$Na_{2}0$	0.0034	0.0039	0.0027	0.0036
Ni0	0.0001	0.0001	0.0001	0.0003
$P_{2}0_{5}$	0.0027	0.0032	0.0021	0.0032
$Pb_{3}0_{4}$	<0.0001	<0.0001	<0.0001	<0.0001
$Sb_{2}0_{3}$	0.0005	0.0006	0.0010	0.0008
$Sc_{2}0_{3}$	<0.0001	<0.0001	<0.0001	<0.0001
$Sn0_{2}$	<0.0001	<0.001	<0.0001	<0.0001
Si0	0.0002	0.0002	0.0001	0.0001
$V_{2}0_{5}$	0.0002	0.0002	0.0002	0.0002
Zn0	0.0001	0.0002	0.0002	0.0002
$Zi0_{2}$	0.0031	0.0032	0.0028	0.0049

X-RAY TESTING

	Fe203	Al203	Ca0	Ti02	Decrepitation
	%	%	%	%	%
-A	0.031	0.025	0.009	0.066	6.4
-B	0.033	0.029	0.013	0.031	-
*TM Sand	0.035	0.033	0.015	0.037	-

23.6+/-3.2

SAMPLE IDENTIFICATION

*THOMAS MOUNTAIN (A) = #TM105 with white "sediment" layer included
" " (B) = #TM105 Typical Ore.

491035

ACI SAND P.02

2 '91 15:19 A.C.I. SYD 02 6998085

FACSIMILE TRANSMITTAL FORM

ACI Glass Packaging Division

SYDNEY

(A Unit of ACI Operations Pty. Ltd.)
613 South Dowling Street, Waterloo, Sydney, Australia
Postal Address: Box 1, P.O. Waterloo. N.S.W. 2017
Telephone: (02) 998 8911
Telex: AA22076

FAX NO. (02) 699 8085

INT. FAX No. 0011 61 2 699 8085

NOTE: Please advise by telex if any parts of transmission have failed.

DATE: 24TH MAY 1991

SENDER: GEOFFREY HIGGINBOTHAM

FAX TO: MINERAL HOLDINGS AUST. (03)6503855

ATTN: NEIL M. THOMAS   CC: G. DEITZ

SUBJECT:

No. of PAGES (including this page) 2

PREPARATION OF SCREENED FRACTIONS OF THOMAS MOUNTAIN SAND

Notes: Since the mesh sizes required overlapped it was not possible to use the same sample of sand to prepare all the material required. Sand (designated A) was screened using BSS Mesh Screens 18, 36, 72, 150 (equivalent to US Mesh Screens 20, 40, 70, 140) until the required quantities of BSS 18/36 (US 20/40) and BSS 36/72 (US 40/70) material had been obtained (about 2.3kg). Sand (designated B) was then screened using BSS Mesh Screens 25, 52, 72, 150 (equivalent to US mesh screens 30, 50, 70, 140) until the required quantity of BSS 25/52 (US 30/50) material had been produced. The BSS 72/150 (US 70/140) material produced from sand 'B' when added to the material produced from sand 'A' exceeds the required amount of 2.3kg. While packed separately then they can be combined to produce a composite sample of the required weight.

Please note that to produce the required quantity of sand has involved screening for over 3 days. During this period staff were actually involved for 25% of the time. The charge will therefore be calculated on the basis of 6 man-hours plus freight.

The larger box contains the screened samples and the smaller box the tailings.

BSS	US	SAND A WT grams	%
+18	+20	120	1.7
-18 +36	-20 +40	2460	34.1
-36 +72	-40 +70	1486	34.5
-72 +150	-70 +140	1619	22.5
-150	-140	526	7.3
		7211	100.1

BSS	US	SAND B	
+25	+30	969	12.0
-25 +52	-30 +50	2475	30.8
-52 +72	-50 +70	1475	18.3
-72 +150	-70 +140	2277	28.3
-150	-140	850	10.6
		8046	100.0

491037

FACSIMILE TRANSMITTAL FORM

Glass Packaging Division

SYDNEY

FAX NO. (02) 699 8085

DATE 06-5-92

SENDER G. Higginbottom

FAX TO ACI Hobart

ATTN Mr. H. Woolley cc. Mr. N. Thomas

SUBJECT Sand M. Thomas

No. of PAGES (including this page) 1

Analysis New Supplier Processed Sand

SiO_2	99.88
Na_2O	0.01
K_2O	<0.01
CaO	<0.01
MgO	<0.01
Al_2O_3	0.02
TiO_2	0.06
Fe_2O_3	0.015
Cr_2O_3	0.0002

Regards

G. Higginbottom

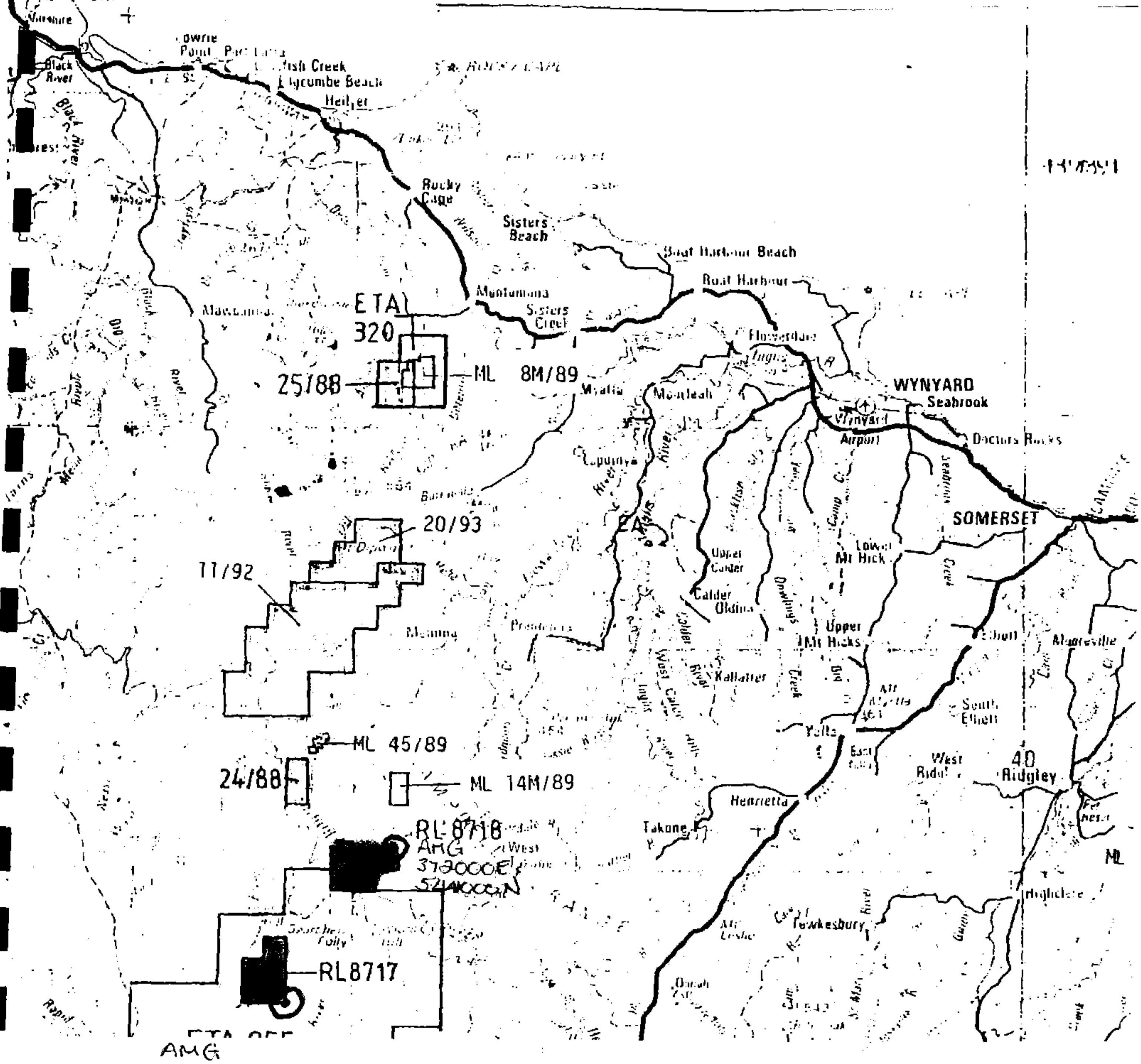
APPENDIX 'E'

MAP OF MHA LICENSES IN N.W. TASMANIA

MINERAL HOLDINGS AUSTRALIA PTY LTD
LEGEND

491039

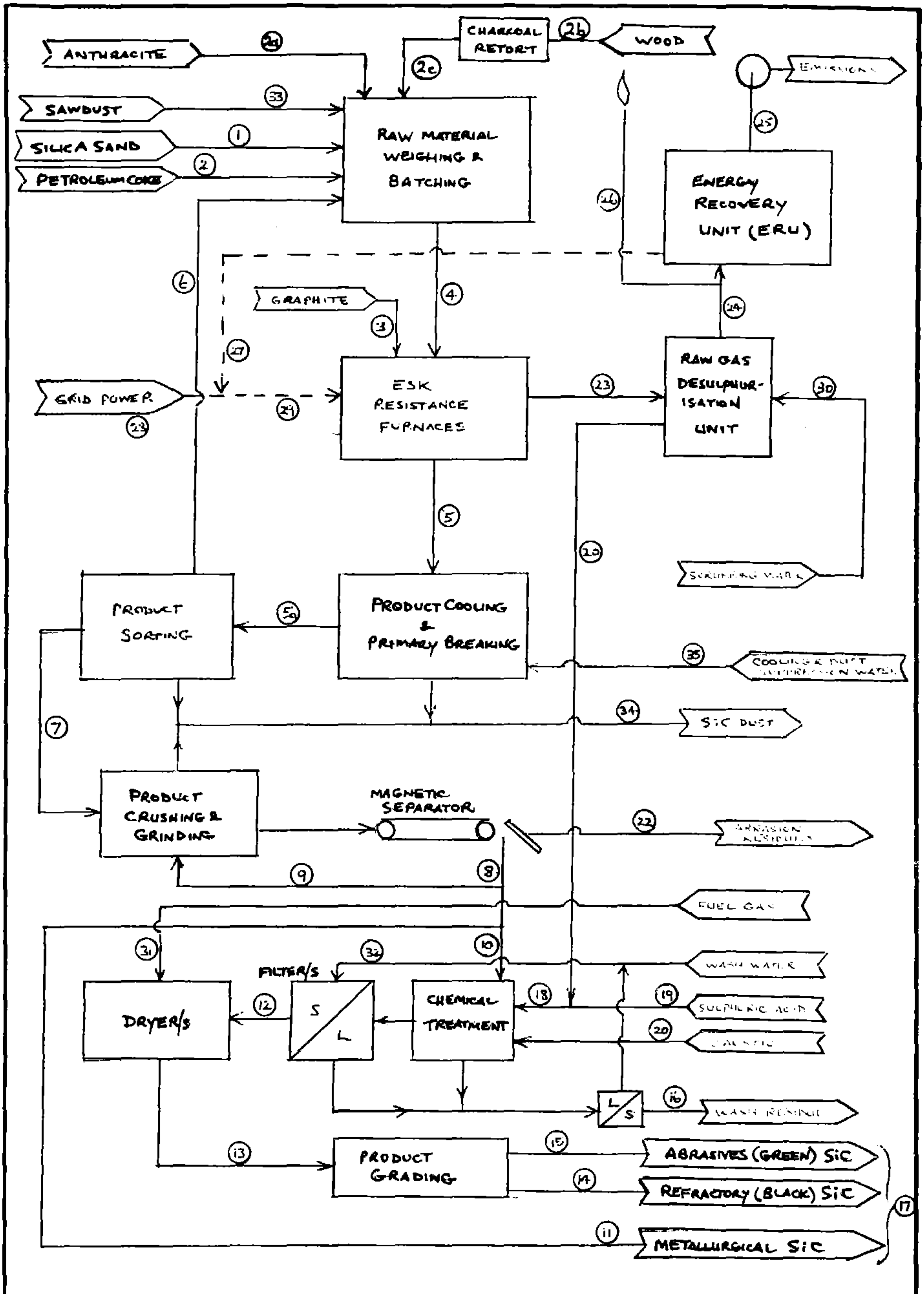
ML.8M/89	THOMAS MOUNTAIN MINE QUARTZUTE/SAND	
EL.24/88 (RL.9602)	SILICA FLOUR CHAMPION'S ROAD	
EL.11/92	MEUNNA SILICA	
ARTHUR KEITH, LYONS RIVER MAGNESITE RL.8717 AND RL.8718		



AMG
367000E
5434000N

AMG REFERENCE POINTS ADDED

Appendix B



DRN. IK		BHP	Silicon Carbide Study - Preliminary Flow Diagram (Amended)	SKETCH No. 16086/001	SHT. No. 1
CHK.					REV. No. B
D.E.		DATE 29/7/99	SCALE NTS		

SILICON CARBIDE PLANT -
CONCEPTUAL FLOWSHEET
MASS & ENERGY BALANCE

Basis:

15,000 tpa SiC production
SiO2 + 3C —> SiC + 2CO 7 MWh/t SiC required
Silica sand @ 99% SiO2, 0.5% Fe2O3, 0.5% Al2O3
Pet coke @ 94% C, 0.1% S
CO + 1/2O2 —> CO2 11.97 MJ/m3 CO
3Fe2O3 + 11C —> 2Fe3C + 9CO
Al2O3 + 3H2SO4 —> Al2(SO4)3 + 3H2O
Turbine efficiency for power from CO = 26%

SiC grades:
Abrasives - 99% SiC
Refractory - 98% SiC
Metallurgical - 90% SiC

Fuel gases:
LPG 93.0 MJ/m3, SG 0.5
Nat gas 40 MJ/m3, SG0.6

Efficiencies & Conversions:
SiC reaction - 75% conversion
SiC drying - 50% heat efficiency
SiC washing - adds 5% water
Product grading - 2% SiC losses
SO2 scrubbing - 95% removal
Sawdust - 4% charge
Assumed acid strength - 30% H2SO4
Assumed caustic strength - 50% NaOH

														Norton specification			Electro Abrasives specifications "Black SiC"	"Green SiC"			
Stream number:	1	2	2a	2b	2c	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	16	17
Stream name:	Silica sand	Pet coke	Anthracite	Wood	Charcoal	Graphite	Raw mix -10mm	Raw product	Pre-sorted	Recycled mix	Sorted product	Crushed SiC	Recycled SiC	High grade SiC	Met grade SiC	Washed SiC	Dried SiC	Refractory SiC	Abrasives SiC	Wash residue	Total SiC
Total tpa	69,000	23,000	9,000	12000	3000	200	55,000	35,764	35,764	18,333	17,421	15,421	5,000	8,421	7,000	8,593	8,163	7,000	1,000	232	15,000
SiC tpa	0	0				0	0	15,272	15,272	0	15,262	15,067	4885	8,767	6300	8,946	8,051	6895	995		14,190
SiO2 tpa	68,862	0				0	91,816	23,279	23,279	22,954	325	321	104	41	280	42	38	35	2		317
C tpa	0	21,620	7,650		2760		39,237	7,373	7,373	7,207	167	164	53	24	140	25	22	21	1		162
Fe tpa	210	0				0	210	1,919	1,919	70	1,849	49	16	7	42	7	6	5.6	0.4	6	48
Al tpa	250	0				0	340	141	141	83	58	57	19	8	49	9	8	7	0.5	8	57
S tpa		690				0	690	230	230	230	0	0	0	0	0	0	0	0	0	0	0

Stream number:	18	19	20	21	22	23	24	25	26	26a	27	28	29	30	31	32	33	34	35	36	37
Stream name:	Wash acid	Caustic	Scrubber water	Recovered S	Abrasion residue	Raw gas	Clean gas	Spent gas	Flare gas	ERU Feed water	Gas power	Grid power	Total power	Dryer steam	Fuel gas	Filter wash water	Sawdust	SiC dust	Cooling water	Salt	
Total tpa	214	52	623	656	2,000	24,504	23193	55,751	4,901	102504				1017	4185	3,152	2200	10	511985	550	
SiC tpa	0	0	0	0	195	0												10			
SiO2 tpa	0	0	0	0	4	0															
C tpa	0	0	0	0	2	0															
Fe tpa	0	0	0	0	1800	0															
Al tpa	0	0	0	0	1	0															
S tpa	0	0	0	656	0	0															
CO tpa	0	0	0	0		19,091	19,091	0	3818												
CO2 tpa	0	0	0	0	0	4033.333333	4,033	27,227	807												
SO2 tpa	0	0	0	0	90	1380	69	69	276												
Electricity GWh	0	0	0	0							12	123	135								
Power rating (MVA)												18	19								
Fuel gas - LPG (GJ)	0	0	0	0											4185						
Sulphuric acid tpa	64	26		32.78																	

Total plant power rating (MVA) 21

Appendix C

491044

	SILICON CARBIDE STUDY - PRELIMINARY EQUIPMENT LIST					
Equip. No.	**Equipment Description**	**Equipment Type**	**Qty**	**Supplier**	**kW**	
Feed Preparation Plant						
	Front end loader		1	Caterpillar		
	Charcoal retorts		2	Lurgi		
	Batching/weighing conveyors		2			
	Batch bins		2			
	Bunker walls in warehouse		1 set			
	Pug mill feed bins		2			
	Pug mills		2	Holland Equipment		
	Dust briquetting plant	OPTIONAL	1	Holland Equipment		
	Foundations/civils					
	Structural steel/platforms/stairs					
Furnaces						
	Furnaces (base, plastic sheets etc	10m x 60m SS base	8	ESK		
	Transformers	ABB 60 MVA	2	ABB		
	Bus bars		16	ABB		
	Heating cores and columns	1m x 1m x 40 m core	8	Showa-Denko		
	Electrical control gear		4	ABB		
	Foundations/civils	15m x 65m x 3m	8			
	Cooling water pipework	100m x 150mm Sch40	8			
	CO monitors	Gastech system - 16 tra	1	Gastech		
	Overhead crane 12.5 tonne		1	Demag		
	FEL for furnace		2	Caterpillar		
Gas Handling Plant						
	Gas collection ductwork		1	HMA		
	Gas de-dusters		1	HMA		
	ERU		1	Babcock-Wilcox		
	Flare		1	John Zink		
	Desulphurisation unit		1	Lurgi		
	Gas plant fans		2			
	Stack		1			
Product Handling Plant						
	Hydraulic breakers		4			
	Pneumatic hammers		32			
	Product bins & grizzlies		4			
	Jaw crusher feed conveyors		2			
	Jaw crusher feed bins		2			
	Jaw crushers		2	Metquip		
	Primary screens		2			
	Jaw crusher recycle conveyors		2			
	Hammer mill feed conveyors		2			
	Hammer mill feed bins		2			
	Hammer mills		2	Humboldt Wedag		
	Secondary screens		2			
	Hammer mill recycle conveyors		2			
	Jet mill feed conveyors		2			
	Recycled furnace mix conveyors		2			
	Chem Treat feed conveyors		2			
	Chem Treat feed bins		2			
	Jet mill feed bins		2			
	Jet mills		2	Alpine		
	Dust collection system		1	DCE-Vokes		
	Foundations/civils					
	Structural steel/platforms/stairs					
	Magnetic separators		2	Eriez		
	Acoustic treatment					
Chemical Treatment Plant						
	Tanks		6			
	Vacuum filters		2	Delkor		

491045

	Dryers		2	Deutsche-Babcock
	Pipework		1	
	Vapour scrubbers		2	Croll-Reynolds
	Foundations/civils	100m x 25m x 2m	1	
	Structural steel/platforms/stairs		1	
	Safety showers		4	
Product Finishing Plant				
	Air classifiers		1	
	Cyclones		4	
	Screens		4	Metquip
	Tube conveyors		4	ICAL
	Bulka bag filling stations		2	
	Bagging stations		4	
	Pallet stacking stations		2	
	Dust collection system		1	
	Foundations/civils			
	Structural steel/platforms/stairs			
	Acoustic treatment			
Water Treatment Plant				
	BFW Plant		1	John Thompson
	Cooling towers	BAC VXT2100	1	G.S.Wagg
	Filters	Sulzer dual media	2	Sulzer
	Pumps	TKL 200x150-500	4	TKL
	Pipework		1	
	Foundations/civils	22m x 12m x 2m	1	
	Structural steel/platforms/stairs		1	
	Chemicals storage & dosing	Nalco dosing systems	1	Nalco
Services				
	Air compressor & dryer	Atlas-Copco GA200	1	Atlas-Copco
	Air receivers	3 m3 each	1	
	Compressed air pipework	200m x 100mm	1	
	Fuel gas storage		1	Boral
	Fuel gas pipework	200m x 100mm	1	
	Steam drums		2	John Thompson
	Steam pipework	1000m x 80mm	1	
	Nitrogen VIE	BOC	1	BOC
	Nitrogen pipework		1	
Infrastructure				
	Control rooms		3	ATCO
	Laboratory building		1	
	Admin building		1	
	Amenities		1	
	Sewerage		1	
	Roads		1	
	High voltage power lines		1	
	Substation/switchyard		1	
	Potable water		1	
	Lighting		1	
	Fencing		1	

Notes:
Where capital costs have been estimated from costs for similar equipment of different capacity, the 0.6 rule has been us
except in the case of gas de-dusting where a factor of 0.45 is used.

Appendix D

	SILICON CARBIDE STUDY - BUDGET CAPITAL ESTIMATE (+/-50%)										
Equip. No.	**Equipment Description**	**Equipment Type**	**Qty**	**Supplier**	**kW**	**Unit $**	**Install'n factor**		**Total $**		**Reference**
Feed Preparation Plant											
	Front End Loader for stockpile		1						750,000		
	Charcoal retorts		2	Lurgi		2,500,000			5,000,000		Simcoa Ops Study
	Warehouse Storage Building	120m x 30m x 7 m high	1			1,980,000			1,980,000		
	Batch bins & Weighing Equipment		2			500,000			1,000,000		
	Bunker Walls in Warehouse		1	set		500,000			500,000		
	Pug mills		2			630,000			1,260,000		
	Dust briquetting plant	Optional									
	Foundations/civils		9,240,000			12%			1,108,800		
	Structural steel/platforms/stairs		9,240,000			5%			462,000		
								Subtotal	**12,060,800**		
Furnaces											
	Furnaces (base, plastic sheets etc	10m x 60m SS base	8			1,872,000	1.5		22,464,000		Fernz Spec. Chemicals
	Transformers	ABB 60 MVA	2			1,860,000	1.2		4,464,000		TEMCo 54 MVA Transformer
	Bus bars		16			100,000	1		1,600,000		TEMCo 54 MVA Transformer
	Heating cores and columns	1m x 1m x 40 m core	8			360,000	1		2,880,000		SSM Graphite price
	Electrical control gear		4			186,000	1		744,000		% estimate on transformer
	Foundations/civils	15m x 65m x .4m	8			370,500	1		2,964,000		$950/m3 for concrete
	Cooling water pipework	100m x 150mm Sch40	8			13,200	2		211,200		JP 100NB piping estimate
	CO monitors	Gastech system - 16 tra	1			56,637	1.22		69,098		TEMCo Fce #4 Study
	Overhead Crane 12.5 Tonne	Demag	1			1,000,000	1.2		1,200,000		
	Front End Loader for furnace		2			750,000	1		1,500,000		
								Subtotal	**35,396,298**		
Gas Handling Plant											
	Gas collection ductwork										
	Gas de-dusters		1			1,550,000	1		1,550,000		HMA quote, TEMCo
	ERU		1			6,000,000	1		6,000,000		TEMCo
	Flare		1			100,000	1		100,000		TEMCo Fce #3
	Desulphurisation unit		1			3,700,000	1		3,700,000		
	Gas plant fans		2			500,000	1.2		1,200,000		
	Stack		1			100,000	1.2		120,000		
								Subtotal	**12,670,000**		
Product Handling Plant											
	Hydraulic breakers		4								
	Pneumatic hammers		32								
	Product bins & grizzlies		4								
	Jaw crusher feed conveyors		4								
	Jaw crusher feed bins		4								
	Jaw crushers		4								
	Primary screens		4								
	Jaw crusher recycle conveyors		4								
	Hammer mill feed conveyors		4								

491047

	Hammer mill feed bins		4									
	Hammer mills		4									
	Secondary screens		4									
	Hammer mill recycle conveyors		4									
	Jet mill feed conveyors		2									
	Recycled furnace mix conveyors		2									
	Chem Treat feed conveyors		2									
	Chem Treat feed bins		2									
	Jet mill feed bins		2									
	Jet mills		2									
	Dust collection system		1									
	Foundations/civils											
	Structural steel/platforms/stairs											
	Magnetic separators											
	Acoustic treatment											
								Subtotal	**35,000,000**			
Chemical Treatment Plant												
	Tanks		6			50,000	1.2		360,000			
	Vacuum filters		2			100,000	1.5		300,000			
	Dryers		2			300,000	2		1,200,000			
	Pipework		1			81000	1		81,000		10% of equipment	
	Vapour scrubbers		2			20,000	2		80,000		AMCL scrubbers	
	Foundations/civils	50m x 25m x.5m	1			593,750	1		593,750		$950/m3	
	Structural steel/platforms/stairs		1	2,381,000		119,050	1		119,050		5% of equipment	
	Safety showers		4			1000	1.2		4,800			
								Subtotal	**2,738,600**			
Product Finishing Plant												
	Air classifiers		1									
	Cyclones		4									
	Screens		4									
	Tube conveyors		4									
	Bulka bag filling stations		2									
	Bagging stations		4									
	Pallet stacking stations		2									
	Dust collection system		1									
	Foundations/civils											
	Structural steel/platforms/stairs											
	Acoustic treatment											
								Subtotal	**5,000,000**			
Water Treatment Plant												
	BFW Plant		1			1,200,000	1		1,200,000			
	Cooling towers	BAC VXT2100	1			257,572	1.5		386,357		TEMCo Fce #4 Study	
	Filters	Sulzer dual media	2			144,703	2		578,813		SSM WTP Upgrade	
	Pumps	TKL 200x150-500	4			19,845	2		158,760		TEMCo Fce #4 Study	
	Pipework		1			57,236	1		57,236		8% of equipment	
	Foundations/civils	16m x 12m x .3m	1			54,720	1		54,720		$950/m3	
	Structural steel/platforms/stairs		1	2,435,886		121,794	1		121,794		5% of equipment	
	Chemicals storage & dosing	Nalco dosing systems	1			27,563	1.5		41,344		TEMCo Fce #4 Study	
								Subtotal	**2,599,024**			
Services												
	Air compressor & dryer	Small Service Unit	1			15,000	1.2		18,000		TEMCo Fce #4 Study	
	Air receivers		1			3,500	1.1		3,850			

49048

	Compressed air pipework		1			21000	1		21,000			
	Natural Gas Piping		1			40,000	1.2		48,000			
	Valves & Metering		1			21000	1		21,000			
	Steam drums		2			50,000	1.5		150,000			
	Steam pipework	1000m x 80mm	1			78000	1		78,000			
	Nitrogen VIE	Small Unit	1	Rental Unit with gas ch		0	1		-			
	Nitrogen pipework		1			5000	1		5,000			
								Subtotal	**344,850**			
<u>Infrastructure</u>												
	Control rooms Basic Structures ATCO		3			40,000			120,000			
	Laboratory building		1			500,000			500,000			
	Admin building		1			800,000			800,000			
	Amenities		1			500,000			500,000			
	Sewerage		1			750,000			750,000			
	Roads		1			500,000			500,000			
	High voltage power lines		1			1,500,000			1,500,000			
	Substation/switchyard		1			5,000,000			5,000,000			
	Potable water		1			1,200,000			1,200,000			
	Lighting		1			500,000			500,000			
	Fencing		1			250,000			250,000			
								Subtotal	**11,620,000**			
Total Cost Equipment & Infrastructure									**117,429,572**			
<u>Engineering, Procurement & Construction Management: @ 10%</u>								**EPCM**	**11,742,957**			
<u>Contingency 20%</u>						CONTINGENCY		**20%**	**25,834,506**			
							GRAND TOTAL =		**155,007,035**			
Notes:												
Where capital costs have been estimated from costs for similar equipment of different capacity, the 0.6 rule has been used,												
except in the case of gas de-dusting where a factor of 0.45 is used.												

491049

491050

Appendix E

491051

**SILICON CARBIDE PLANT (15,000 TPA) -
ESTIMATED OPERATING COSTS - VICTORIA**

Item:	*Units*	*$/unit*	*Units/t SiC*	*$/t SiC*	*Reference*
Silica sand*	t	90	1.53	137.7	massbal2.xls
Petroleum coke	t	430	0.29	124.7	massbal2.xls
Anthracite	t	133	0.34	45.22	massbal2.xls
Charcoal	t	100	0.32	32	massbal2.xls
Sawdust	t	25	0.15	3.75	massbal2.xls
Salt	t	78	0.04	3.12	massbal2.xls
LPG	GJ	6	0.45	2.7	massbal2.xls
Electricity	MWh	35	7.83	274.05	massbal2.xls
Water	kL	0.8	8	6.4	massbal2.xls
Sulphuric acid (98%)	t	160	0.004	0.64	massbal2.xls
Caustic (50% NaOH)	t	100	0.003	0.3	massbal2.xls
Graphite	t	4000	0.01	40	massbal2.xls
Labour	manhours	30	7	210	
Waste disposal	t	150	0.07	10.5	massbal2.xls
Maintenance @5%capex				8	
Depreciation @10%capex				16	
Technology fee	yr	2000000	0.000022	44	Basis - Alcan tech. fee for Mg
Production materials (sheeting, breaker tips etc)				150	
Total operating cost				**1109.08**	

*includes mining & freight

491052

SILICON CARBIDE PLANT (15,000 TPA) -
ESTIMATED OPERATING COSTS - VICTORIA

Item:	*Units*	*$/unit*	*Units/t SiC*	*$/t SiC*	*Reference*
Silica sand	t	90	1.53	137.7	massbal2.xls
Petroleum coke	t	430	0.29	124.7	massbal2.xls
Anthracite	t	133	0.34	45.22	massbal2.xls
Charcoal	t	100	0.32	32	massbal2.xls
Sawdust	t	25	0.15	3.75	massbal2.xls
Salt	t	78	0.04	3.12	massbal2.xls
LPG	GJ	6	0.45	2.7	massbal2.xls
Electricity	MWh	35	9	315	massbal2.xls
Water	kL	0.8	8	6.4	massbal2.xls
Sulphuric acid (98%)	t	160	0.004	0.64	massbal2.xls
Caustic (50% NaOH)	t	100	0.003	0.3	massbal2.xls
Graphite	t	4000	0.01	40	massbal2.xls
Labour	manhours	30	7	210	
Waste disposal	t	150	0.07	10.5	massbal2.xls
Maintenance @5%capex				7	
Depreciation @10%capex				14	
Technology fee	yr	2000000	0.000022	44	Basis - Alcan tech. fee for Mg
Production materials (sheeting, breaker tips etc)				150	
Total operating cost				**1147.03**	

491053

SILICON CARBIDE PLANT (15,000 TPA) - ESTIMATED OPERATING COSTS - TASMANIA

Item:	*Units*	*$/unit*	*Units/t SIC*	*$/t SIC*	*Reference*
Silica sand	t	65	1.53	99.45	massbal2.xls
Petroleum coke	t	430	0.29	124.7	massbal2.xls
Anthracite	t	133	0.34	45.22	massbal2.xls
Charcoal	t	100	0.32	32	massbal2.xls
Sawdust	t	25	0.15	3.75	massbal2.xls
Salt	t	78	0.04	3.12	massbal2.xls
LPG	GJ	6	0.45	2.7	massbal2.xls
Electricity	MWh	40	9	360	massbal2.xls
Water	kL	0.8	8	6.4	massbal2.xls
Sulphuric acid (98%)	t	160	0.004	0.64	massbal2.xls
Caustic (50% NaOH)	t	100	0.003	0.3	massbal2.xls
Graphite	t	4000	0.01	40	massbal2.xls
Labour	manhours	30	7	210	
Waste disposal	t	150	0.07	10.5	massbal2.xls
Maintenance @5%capex				7	
Depreciation @10%capex				14	
Technology fee	yr	2000000	0.000022	44	Basis - Alcan tech. fee for Mg
Production materials (sheeting, breaker tips etc)				150	
Total operating cost				**1153.78**	

491054

SILICON CARBIDE PLANT (15,000 TPA) - ESTIMATED OPERATING COSTS - TASMANIA

Item:	*Units*	*$/unit*	*Units/t SiC*	*$/t SiC*	*Reference*
Silica sand*	t	65	1.53	99.45	massbal2.xls
Petroleum coke	t	430	0.29	124.7	massbal2.xls
Anthracite	t	133	0.34	45.22	massbal2.xls
Charcoal	t	100	0.32	32	massbal2.xls
Sawdust	t	25	0.15	3.75	massbal2.xls
Salt	t	78	0.04	3.12	massbal2.xls
LPG	GJ	6	0.45	2.7	massbal2.xls
Electricity	MWh	40	7.83	313.2	massbal2.xls
Water	kL	0.8	8	6.4	massbal2.xls
Sulphuric acid (98%)	t	160	0.004	0.64	massbal2.xls
Caustic (50% NaOH)	t	100	0.003	0.3	massbal2.xls
Graphite	t	4000	0.01	40	massbal2.xls
Labour	manhours	30	7	210	
Waste disposal	t	150	0.07	10.5	massbal2.xls
Maintenance @5%capex				8	
Depreciation @10%capex				16	
Technology fee	yr	2000000	0.000022	44	Basis - Alcan tech. fee for Mg
Production materials (sheeting, breaker tips etc)				150	
Total operating cost				**1109.98**	

*includes mining & freight