TWO DECADES OF MANGANESE ALLOY SMELTING IN TASMANIA, AUSTRALIA

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ABSTRACT

The Temco Plant was established in Tasmania to meet the increasing needs of the Australian Steel Industry for the major ferro alloys and manganese alloys in particular. The industry was established on imported manganese ores but in 1966 a major ore body was developed at Groote Eylandt, and coupled with the installation of a second furnace at Temco provided the basis for an independent manganese alloy industry to meet future needs.

As steel production increased the decision was made in 1976 to expand and rationalise the alloy industry in Tasmania using modern large furnaces with pollution control and improved practices for optimum efficiency and utilisation of raw materials.

The existing facilities on the Temco site and proposed alterations to meet future challenges are examined.

INTRODUCTION

The Tasmanian Electro Metallurgical Company Pty. Ltd. (Temco) is situated at Bell Bay in Tasmania, and is the only producer of ferro alloys in Australia.

Temco is a wholly owned subsidiary of the Broken Hill Proprietary Company Limited, the largest public company in Australia. Production of ferro alloys commenced in May 1962 with the commissioning of Number 1 Furnace rated at 13.2 MVA with the production of high carbon ferromanganese only. In 1966 Number 2 Furnace of 16 MVA was commissioned at Temco and at the same time the Groote Eylandt manganese ore mine was commissioned as the only viable manganese ore source in Australia.

In 1976 and 1977 an expansion of facilities took place during which a 27MVA ferromanganese silicomanganese furnace (see Figure 1) a 45MVA ferrosilicon furnace and a manganese ore sinter plant were commissioned. Table 1 details furnace parameters at Temco

In 1981 a 1.75MW induction furnace was commissioned for the melting of alloy fines.

In 1974 the ferro alloy plant situated at BHP Newcastle Steelworks was closed down, which left Temco as the only ferro alloy smelter in Australia.

BRIEF HISTORY

In 1962 Number 1 Furnace rated at 13.2 MVA was approximately one third larger than the world's largest furnace at that time for the production of ferromanganese. Production was based on manganese ores imported from South Africa and because of the high ratio of iron to manganese the alloy produced was 70% manganese. With the advent of the Groote Eylandt manganese deposit it was possible to produce standard high carbon ferromanganese, that is 76% minimum manganese and to produce silicomanganese by the Duplex process for maximum recovery of manganese units. Initially the silicon content required by Australian Steelmakers was specified as 11-13% silicon but in the early 1970's the specification for silicon was increased to 15-17% silicon with the manganese content remaining at 65-68%.

With the closure of the Ferro Alloy Smelter at Newcastle additional capacity was installed at Bell Bay to provide BHP requirements for manganese alloys and ferrosilicon with some provision for export. In recent years the specification for silicomanganese has risen to 16-18% silicon. High carbon ferromanganese with manganese content 78% minimum is in demand for export markets.

For maximum recovery of manganese units a small induction furnace was installed to melt ferromanganese, silicomanganese, and ferrosilicon fines produced during the crushing operation.

MANGANESE MINE - Groote Eylandt

Groote Eylandt Mining Company Pty. Ltd. (Gemco) is a wholly owned subsidiary of the Broken Hill Proprietary Company Limited (BHP Australia). Its operations are based on Groote Eylandt a large island some 2260 square kilometres in area lying 48km from the coast of Arnhem Land and about 650km east-south-east of Darwin. The Groote Eylandt Mining Company was formed in 1964 and work commenced on the construction of a port, township, mine and treatment plant, with the initial objective of supplying 70,000t per year of dressed ore to meet BHP's manganese requirements. In March 1966 the first shipment of ore for smelting at Temco was loaded. The prospects of marketing the ore overseas had been investigated, and six months later the first export shipment left for Japan. Late in 1968 preparation began for the design and construction of a beneficiation plant to produce 1 million tonnes per year of lump ore. Extensive metallurgical testing was carried out to enable the plant to be designed to handle the wider range of ores to be mined, and to produce a range of different products of consistent grade and quality. Construction of the new plant took place in 1971 and commissioning began late that year. The plant went into full operation in March 1972.

Geology

The manganese ore at Groote Eylandt occurs as a relatively flat tabular stratum within Lower Cretaceous sands and clays deposited over an irregular basement of Proterozoic sandstones (the Groote Eylandt beds) during a marine transgression 50 million years ago. The initial deposition appears to have been in near-shore shallow tidal areas and to have been caused by the precipitation of manganese oxide from sea water under appropriate conditions of temperature and chemical environment. The major ore type comprises primary pisolites which have been recemented. Agglomerates of pisolites are found in some locations, whereas in other areas more massive structures have resulted.

The ore horizon is overlain by sandy clay and a lateritised conglomerate which varies in thickness and lateral extent. This laterised conglomerate is thought to be of Tertiary age. The ore in turn lies on consolidated sands and clays with claystones and mudstones which have little strength.

The principal ore minerals are pyrolusite, cryptomelane and psilomelane. Some horizontal zoning of the orebody occurs, varying from cemented to loose pisolites and textureless ore, with some clay bondings present in places.

The reserves of ore on Groote Eylandt are at least 300 Million tonnes of high grade in situ material (average 40% manganese) with potential for substantial additional tonnages to be proved.

Recovery of export quality product after treatment is above 50% and hence Groote Eylandt can and will continue to be a major supplier of ore to the world markets.

Mining

The ore is mined by open cut methods from various quarries simultaneously and blended to produce the required products. The ore body is stripped of its overburden using trucks and excavator, or large open bowl scrapers which are either push loaded or utilise the push/pull tandem operation. Most of the stripped ore is drilled and blasted. Ore is loaded into off highway haulage trucks by front end loaders and backhoe configuration hydraulic excavators. The haulage distance can vary from two to eight kilometres depending on the quarry being mined.

The run of mine ore is crushed, scrubbed, sized, and if required by the product specification, fed through a lump or fine dense medium separation circuit. The product ore is trucked to the port stockpiles for blending and shipment.

Figure 2 is a simplified flow chart which depicts the process. Mined out areas are restored and rehabilitated.

RAW MATERIALS

Raw materials for the Temco Plant are almost exclusively obtained within Australia, and details of the specifications are provided in Table 2. The only raw material imported is electrode paste.

From 1962-1966 manganese ores were imported for ferromanganese production and because of limitations on manganese content the alloy produced was 70% manganese. It was possible following Groote Eylandt's commissioning to produce standard high carbon ferromanganese and manganese lump ore was smelted exclusively until 1976 when the Sinter plant was commissioned. The Sinter plant for the first time afforded the opportunity to include pre-reduced ore into the charge and considerable experience has been gained with a variety of proportions of sinter to lump ore in recent times. The plant has standardised on 65% sinter expressed as a percentage of the total ore input and this decision is based on the economics of the plant. Acid sinter is preferred.

Silicomanganese production is mainly from ferromanganese slag, silicomanganese grade sinter, and manganiferous ore for grade control.

Quartzite and quartz are sourced from Beaconsfield in Tasmania and Whyalla in South Australia respectively. The blending of the two silica sources optimises economics and smelting conditions for both ferrosilicon and silicomanganese production. Thermal stability, high silica content and low alumina contamination are characteristic of both grades.

Fluxes in the form of dolomite from Ardrossan in South Australia and limestone from Beaconsfield are readily available and utilised for ferromanganese and silicomanganese operations.

Blast furnace coke is the prime reductant and is obtained from screenings at the Newcastle and Whyalla Steelworks. Coal is a valuable additive for ferrosilicon smelting and woodchips obtained locally enhance charge porosity. Woodchip additions substantially improve operating conditions, assist in the quantity of alloy fines which can be recycled and reduce clinker formation.

Raw materials are screened after crushing at 6mm for coke and 9mm for ores. Fines in raw materials are extremely detrimental, causing poor charge porosity, which will result in high power consumption per tonne of alloy, high furnace top temperatures, excessive fume and dust losses, low production, and contribute to furnace eruptions. The fines are included in the constituents for sinter production together with alloy fines. In this way complete utilisation of raw materials is practised and smelting conditions in the alloy furnaces are enhanced by removal of fines and conversion to hard porous sinter.

The inclusion of up to 4% ferromanganese alloy fines is an efficient method for recycling unsaleable alloy and at the same time reduces the coke required for sintering.

Sintering of manganese ore fines produces a hard porous sinter which withstands the rigours of handling much better than iron ore sinters. Sinter is superior to manganese ore as well, and withstands degredation when transported large distances even when multiply handled. Hardness is a simple function of coke addition in the sinter mix and the quality desired can be obtained by adjustment.

The flexibility of the sinter strand provided with on strand cooling affords Temco a useful outlet for ferromanganese slag fines, quartzite fines and limited quantities of raw material spillages. These materials when proportioned into the sinter mix provide economic additions for silicomanganese smelting.

SINTERING PROCESS

The Sinter machine has a sintering grate area of 18m². The strand is a 36m² machine and incorporates on strand cooling. Although designed initially to produce 600 tonnes per day, improvements have resulted in an average production of 750 tonnes per day with the current production peak of 925 tonnes per day.

The sinter flow diagram is shown in Figure 3 as an integral production path for ferro alloy production.

Sintering of Groote Eylandt manganese ore fines is similar to the acid sintering of iron ores. As with this type of sintering of iron ores the bonding material consists of fayalite (2 FeO . SiO_2) and glass. A quantitative mineralogical analysis of sinter produced the results shown in Table 3.

TABLE NO. 3

Mineralogical Analysis of a sample of Manganese Sinter.

Phase		Volume
Hausmannite	(Mn_3O_4)	74
Rhodonite	($Mn\ SiO_2$)	1
Fayalite	($2\ FeO.\ SiO_2$)	6
Fayalite/glass eutectic		7
Glass (amorphous)		9
Magnetite	(Fe_3O_4)	2
Hematite	(Fe_2O_3)	1
TOTAL		100

Production of basic sinter reduces productivity and hence is unattractive economically. Benefits may be obtained in the smelting process through the use of basic sinter in lieu of acid sinter, and some reduction in SO_x emissions in the sintering operation are achieved, but the transport properties of basic sinter are inferior to acid.

Benefits of the use of Sinter in Manganese Alloy Production

1. Complete utilisation of raw materials.
2. Stability of furnace operating conditions.
3. Low furnace top temperatures.
4. Deep electrode penetration.
5. Reduced fume emission.
6. Drastic reduction in electrode paste consumption.
7. Reduced furnace maintenance.
8. Lower furnace gas make.
9. Increased charge porosity.
10. Increased quantity of alloy fines recycled.
11. Increased electrical loading.

FERROMANGANESE SMELTING

A typical material balance of charge constituents for the production of ferromanganese is shown in Figure 4.

Trials have been conducted over the years varying the proportion of sinter in the ferromanganese operation and at this point in time sinter constitutes 65% of the total ore input as the optimum compromise between economic considerations and operations.

The ferromanganese slag is stockpiled for smelting as the major source of manganese in the silicomanganese operation.

SILICO MANGANESE SMELTING

A typical material balance for the production of silicomanganese is shown in Figure 5.

The production of silicomanganese has changed from 1966 when the silicon specification was 11/13% and alloy produced was exclusively for the domestic market. As the plant expanded the need arose to rationalise smelting specifications to match the international market so silicon specifications increased to 15/17% and later 16/18%. Silicomanganese is produced almost exclusively in Numbers 1 and 2 furnaces, while Number 3 furnace concentrates on ferromanganese production.

TAPPING AND CASTING

Manganese alloys are cast in layers to minimise contamination and fines generation. A drawback of this method is in the dust or air borne dust generated and considerable efforts have been made to find alternatives to overcome this problem.

FINISHED PRODUCT CRUSHING AND SCREENING

Alloy is sized into the following ranges

+ 100 mm
100 x 60 mm
60 x 10mm
10 x 5mm
-5 mm

Fines are recycled through the Sinter plant, Induction furnace and the three manganese smelting furnaces. Alloy is provided to customers in bulk or in 200 litre steel drums.

TRANSPORT SYSTEMS AND FINES GENERATION

With the recession in the steel and ferro alloy industry a buyer's market has continued and increasing attention is given to alloy specifications, sizing specifications, and in particular fines generation. Handling methods to minimise fines generation as well as research into the friability characteristics of alloys, and in particular cooling rate, have led to the development of a variety of handling systems.

INDUSTRIAL HEALTH

Fume emissions and dust emissions as well as toxic substances associated with the smelting process receive increased attention because of the obvious effect of such substances on the health and welfare of the workers on the site. In particular provision for the collection of emissions such as these are incorporated in an overall plan to improve the working conditions on the plant. Monitoring of the health of workers is performed on a routine basis.

ENVIRONMENTAL CONSIDERATIONS

In recent years attention to environmental matters with respect to air and water pollution has become of paramount importance for the operation of all ferro alloy smelters. Numbers 1 and 2 Furnaces were built at a time when regulations for environmental emissions did not exist and Government authorities are undertaking programmes to plan the control of air and water emissions from industries. Number 1 and 2 Furnaces at Temco are equipped with Buffalo scrubbers which wash the fume, which is then collected in settling ponds. The overflow water is not treated. Plans are under way to replace the settling ponds with a high rate clarifier as shown in Figure 6. This system incorporates spare capacity available in the Number 3 Furnace gas cleaning plant system.

Number 1 and 2 Furnaces during periods of gas cleaning plant maintenance vent fume to atmosphere. Provision will be made for a standby Venturi scrubbing system to be constructed as a common provision for the furnaces to prevent this emission. Because of the design of the furnace covers leakage occurs from the seals around the electrodes. Because of the peculiar construction of the electrode case seal re-design is not possible and provision will be made to incorporate a baghouse to collect fume from this source.

Gas from Number 3 27MVA closed manganese furnace is cleaned in two stage venturi scrubbers with closed circuit treatment of effluent water in a thickener and collection of the solids is a filter cake at a rotary drum. Recovery of the manganese contained in the filter cake represents a challenge and our current direction is concentrated in the area of new products not produced at Temco at the present, namely manganese metal and Electrolytic Manganese Dioxide. The Sinter machine has three systems of dust collection. Dust in the waste gas from sintering is removed by a double field electrostatic precipitator while dust from on-strand cooling is collected in multi clones. Plant de-dusting and removal of dust from materials and product handling is effected by means of a bag filter with reverse air flow for bag cleaning. Dust collected from all three systems is transported by conveyors to the sinter feed mixing drum for recycling.

GOVERNMENT INCENTIVES AND PROTECTION

Within Australia there is no protection of the ferro alloy industry at all in the form of duties etcetera, nor is there any financial incentive to export alloys, other than the business advantages of a free enterprise system; that is profit. The benefit of Government protection is being pursued by a number of countries as a means of protecting inefficient industries and other Governments offer incentives to subsidise their particular industries to export material with financial advantage. Both of these protectionist systems have developed to the stage where technically advanced low cost producers cannot export and compete on an equal basis with local producers. The effect of this type of action is counter productive to the industry.

RESEARCH AND DEVELOPMENT

A programme for the research of the industry and development of processes associated with process efficiency and utilisation of waste products as well as the development of new products is a function undertaken at the plant and at the two research establishments of the parent company situated at Melbourne Research Laboratories and Newcastle Central Research Laboratories.

ADVANTAGES OF PRODUCING FERRO ALLOYS IN TASMANIA

1. The power generation authority, the Hydro-Electric Commission, depends almost exclusively on the hydro electric schemes to provide reasonably priced electricity to industrial users. The Grid is being expanded with a development on the Gordon River below the Franklin River.

2. The Port of Bell Bay is a deep all weather port ideally situated one mile from the Temco Plant. Transport of raw materials inwards and finished product outwards is by road transport.

   Temco has priority use of Number 3 berth which is able to cater for ships up to a draught of 37 feet. The wharf is provided with a 12½ tonne luffing crane for grab loading and discharge.

3. An industrially stable and readily available workforce.

4. Politically stable Government.

FUTURE TRENDS

There are noticeable trends in the Australian industry which serve as a warning to the ferro alloy industry and may in fact result in the demise of the industry as it now exists. There is a tendency for improvements in technology in steel making to maximise the use of the bulk ferro alloys with the elimination of the more sophisticated highly priced alloys. This coupled with trends to utilise an ever increasing proportion of continuously cast steel which increases the yields without increasing steel make may well result in diminishing requirements for manganese alloys. Taken to its next step, which has already developed in research laboratories, manganese may be added in the form of raw ore at various stages of the steel making process to reduce the need of alloys even more severely. The only off-setting trend is the increased production of higher manganese content steels which result in low weight high strength steels which can substitute for normal steel grades.

As BHP in Australia rationalises its steel making facilities the opportunity exists for the Company to utilise excess blast furnace capacity to produce ferromanganese for its own usage and overcome quality problems by metallurgical adjustments at various stages during the steel making process. Utilisation of fines by injection processes enable fine tuning of steel specifications so that strict alloy specifications become less critical.

At ferro alloy plants with current limitations on capital expenditure and the depressed economic circumstances of a number of smelters those producers fortunate enough to have installed technologically advanced equipment such as computer control and casting machines are in a more favoured position to face competition.

Geographical locations are playing an important part in determining markets as freight costs are reaching an alarming proportion of total selling price. Alternative processes depending on economics will be introduced to minimise some of the irregularities in performance of raw materials and furnace designs.

Advancements in plasma arc technology as well as advancements in blast furnace technology may replace electric furnace methods in the future.

Temco's future plans are based on the following objectives:

1. Maintain and improve operating performance so that technological changes will maintain our competitiveness.

2. Eliminate areas of inefficiency.

3. Reduce costs of production in all areas from the supply of raw materials up to and including the as received alloy in the customers warehouse.

4. Reduce the amount of manpower per tonne of alloy.

Anticipated advancements at Temco:

1. Replacement of existing layer casting system for manganese alloys with a casting machine which will minimise fines, increase yields, decrease labour and improve the environmental conditions of the workforce.

2. Instal computer control on the furnace operations to optimise smelting conditions and thereby increase our efficiency.

3. Instal technologically advanced smelting equipment as required to replace inefficient aged units.

4. Uprate and replace as required the product handling system up to and including the loading facilities alongside ship to optimise the quality of our products.

5. Pursue vigourously research programmes to eliminate areas of resource loss through changes in methods, work practices and more aggressive and innovative marketing and an entrepeneurial research of new products.

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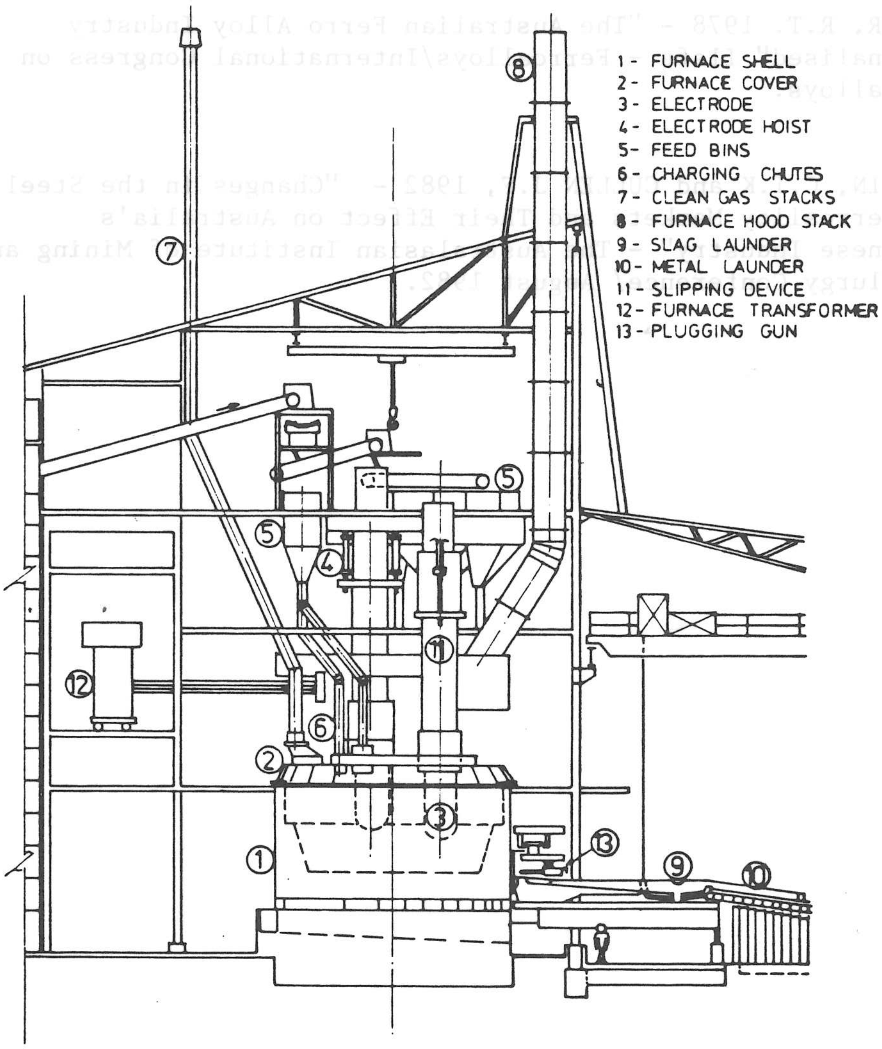

FIGURE 1.

27MVA FERROMANGANESE SILICOMANGANESE FURNACE

TABLE 1 - DETAILS OF FURNACES

	Number 1 Furnace	Number 2 Furnace	Number 3 Furnace	Number 5 Furnace
Commissioning Year	1962	1966	1977	1976
Product	FeMn and SiMn	FeMn and SiMn	FeMn and SiMn	75% FeSi
Type	Rotating, closed	Rotating, closed	Stationary, closed	Rotating, semiclosed
Shell Diameter mm	10,000	10,000	11,000	9,040
Shell Depth mm	5,640	5,640	5,425	4,425
Hearth Diameter mm	9,235	9,235	10,200	8,980
Top of Shell to Hearth mm	3,705	3,705	4,130	3,420
Electrode Diameter mm	1,420	1,420	1,550	1,550
Electrode Spacing f/f mm	1,980	1,980	2,150	1650min - 2050 max
Transformer Capacity kVA	13,200 (16,000)	16,000	27,000	45,000
Primary Voltage V	22,000	22,000	22,000	22,000
Secondary Voltage ΔΔ	92-154V	110-182V	150-235V	190-300V
YΔ	53-89V	64-106V	87-136V	110-173V
Tap Changer	On load 14 taps	On load 19 taps	On load 21 taps	On load 23 taps
Tapholes	3	3	2	6
Hearth Thickness				
- Brick mm	372	372	295	931
- Carbon Block	-	-	1,000	500
- Carbon Paste	1,543	1,543	-	573

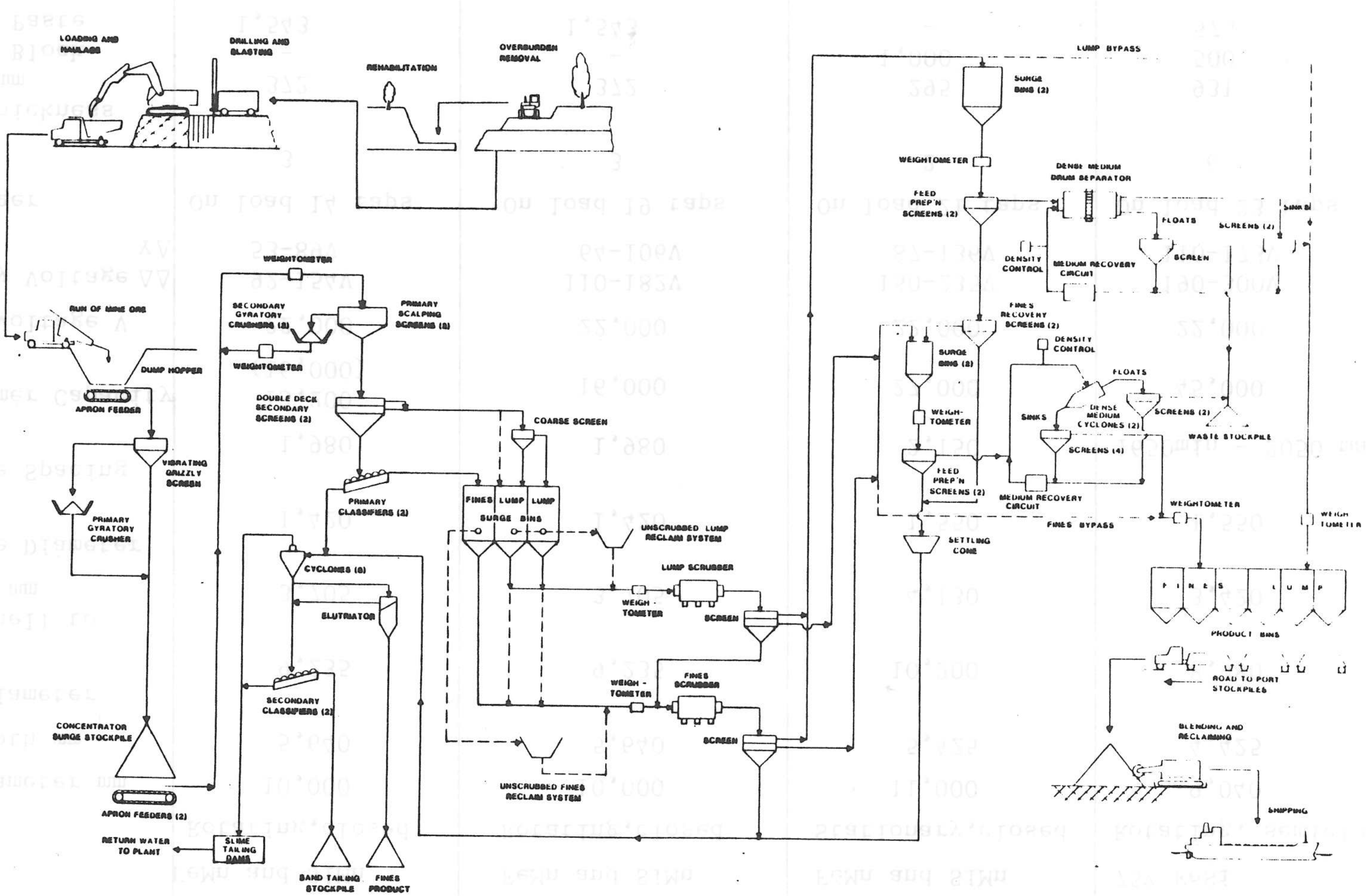

FIGURE 2

FLOW CHART - GROOTE EYLANDT

TABLE NO. 2.
RAW MATERIALS ANALYSIS

Material	Source	V	FC	Ash	Mn	Fe	SiO_2	Al_2O_3	Cao	MgO	P
Coke	Newcastle, N.S.W. Whyalla, South Aust.	0.7	81.5	17.9	-	0.8	9.4	3.9	0.4	0.1	.06
Coal	Newcastle, N.S.W.	30.2	53.5	13.8	-	0.4	7.2	2.8	0.2	0.1	-
Quartzite	Beaconsfield, Tas	-	-	-	-	0.3	98.5	0.4	.01	0.03	.01
Quartz	Whyalla, South Aust.	-	-	-	-	0.5	98.0	0.7	0.1	0.1	.01
Manganese Ore	Groote Eylandt	-	-	-	49.9	2.9	5.8	3.5	0.2	0.1	065
Manganese Ore Metallurgical Fines	Groote Eylandt	-	-	-	49.6	3.5	4.0	4.2	0.1	0.5	058
Manganese Ore Siliceous Fines	Groote Eylandt	-	-	-	41.5	6.7	9.8	6.6	0.1	0.3	065
Manganese Ore H.G. Fines	" "	-	-	-	45.8	5.1	6.4	5.6	0.1	0.3	061
Manganiferous Iron Ore	Whyalla, South Aust.	-	-	-	10.0	58.0	0.4	0.2	0.1	0.2	.07
Iron Ore Pellets	" " "	-	-	-	0.4	63.8	4.9	2.3	0.3	0.2	.04
"	Savage River, Tas.	-	-	-	0.09	66.5	1.94	0.37	.15	1.10	.009
Limestone	Beaconsfield, Tas.	-	-	-	0.02	0.24	1.32	0.48	52.1	2.1	.004
Dolomite	Ardrossan, South Aus.	-	-	-	0.2	0.5	1.5	0.3	30.0	20.5	0.01

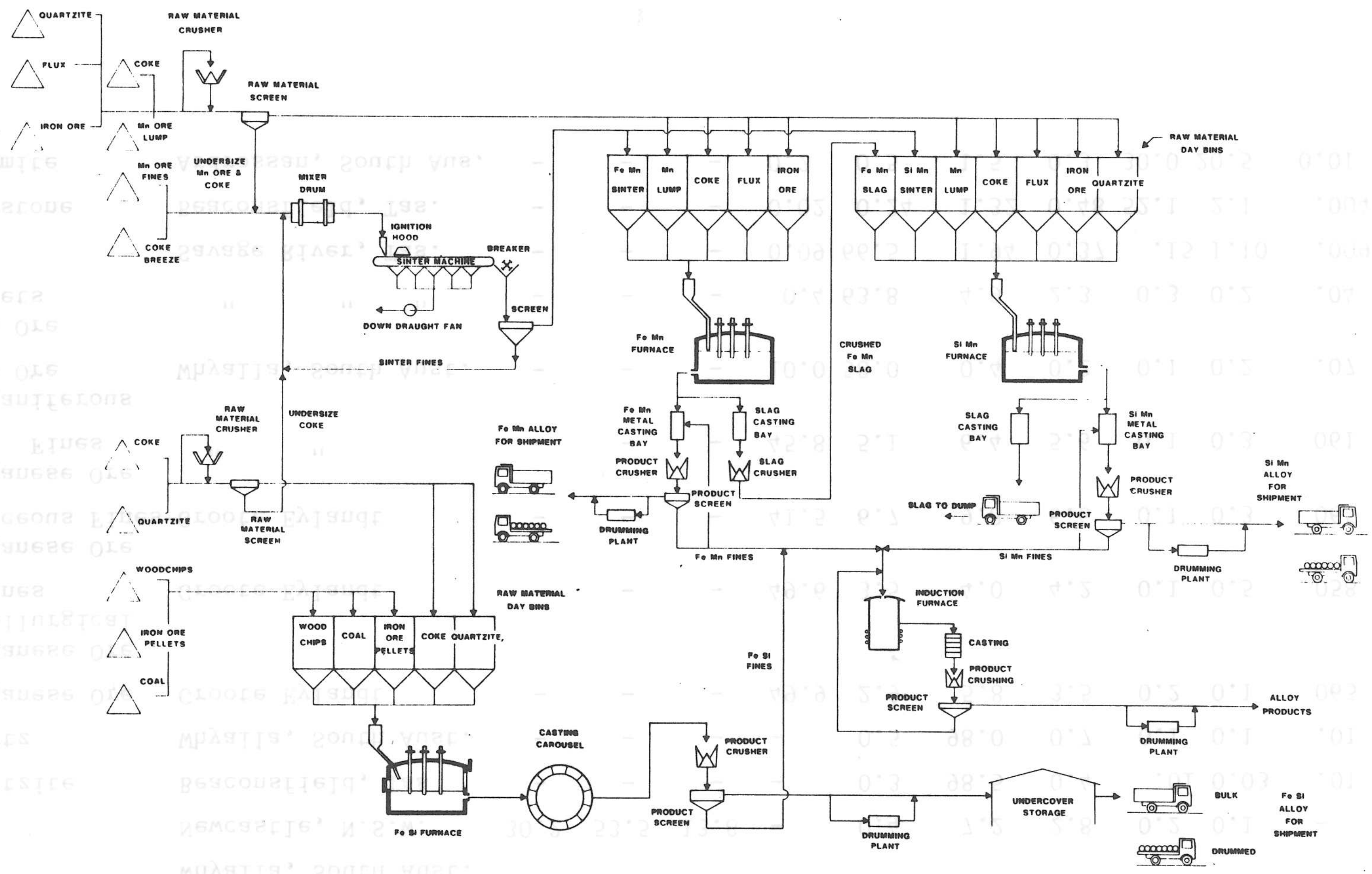

FIGURE 3
TEMCO & SINTER FLOW CHART

FIGURE 4

MATERIAL BALANCE - 76% FERROMANGANESE

MATERIAL	T/T	Mn	MnO	Fe	SiO_2	CaO	MgO	Al_2O_3	C
Sinter	1.270	67.945		7.239	10.668			8.001	
G. E. Lump	0.586	29.241		1.699	3.399	0.117	0.059	2.051	
Whyalla Ore	0.114	1.140		6.612	0.046	0.011	0.023	0.023	
F.G.Limestone	0.112	0.002		0.027	0.148	5.835	0.235	0.054	
R.B. Limestone	0.112			0.045	0.538	5.667	0.179	0.090	
Newcastle Coke	0.466			0.373	4.380	0.186	0.047	1.817	37.979
TOTALS	2.660	0.983		0.160	0.192	0.118	0.005	0.120	0.380
Metal	1.000	0.765		0.160					0.068
Slag	0.741	0.203	0.262		0.183	0.118	0.005	0.120	
Remainder		0.015							
Average Analysis Slag (%)		27.4							
Calc. Analysis Slag (%)			35.4		24.7	15.9	0.7	16.2	

$$\text{Short } \frac{\text{Base}}{\text{Acid}} = 0.67 \qquad \text{Molec } \frac{\text{Base}}{\text{Acid}} = 1.94$$

Manganese recovery metal = 77.8%
Manganese recovery slag = 20.7%
Manganese loss = 1.5%

FIGURE 5

MATERIAL BALANCE - SILICO MANGANESE

MATERIAL	T/T	Mn	MnO	Fe	SiO_2	CaO	MgO	Al_2O_3	C
F. G.Limestone	0.201	0.004		0.048	0.265	10.472	0.422	0.096	
Dolomite	0.201	0.040		0.101	0.302	6.030	4.121	0.060	
Iron Ore	0.126	1.260		7.308	0.050	0.013	0.025	0.025	
Quartzite	0.520			0.156	51.220	0.005	0.016	0.208	
FeMn Slag	1.432	39.237		0.215	39.523	22.769	1.718	19.762	
Coke	0.467			0.374	4.390	0.187	0.047	1.821	38.061
H.G.F. Sinter	0.594	31.482		3.742	4.990			3.564	
G.E. Lump	0.202	10.080		0.586	1.172	0.040	0.020	0.707	
FeSil	0.047			0.940	7.050			0.094	
TOTALS	3.790	0.821		0.135	1.090	0.395	0.064	0.263	0.381
Metal	1.000	0.657		0.135					0.020
Slag	1.786	0.152	0.196		0.742	0.395	0.064	0.263	
Remainder		0.012							
Average Analysis Slag (%)		8.5							
Calc. Analysis Slag (%)			11.0		41.6	22.1	3.6	14.8	

$$\text{Short}\ \frac{\text{Base}}{\text{Acid}} = 0.62 \qquad \text{Molec}\ \frac{\text{Base}}{\text{Acid}} = 0.92$$

Manganese recovery metal = 80.0%
Manganese recovery slag = 18.5%
Manganese loss = 1.5%

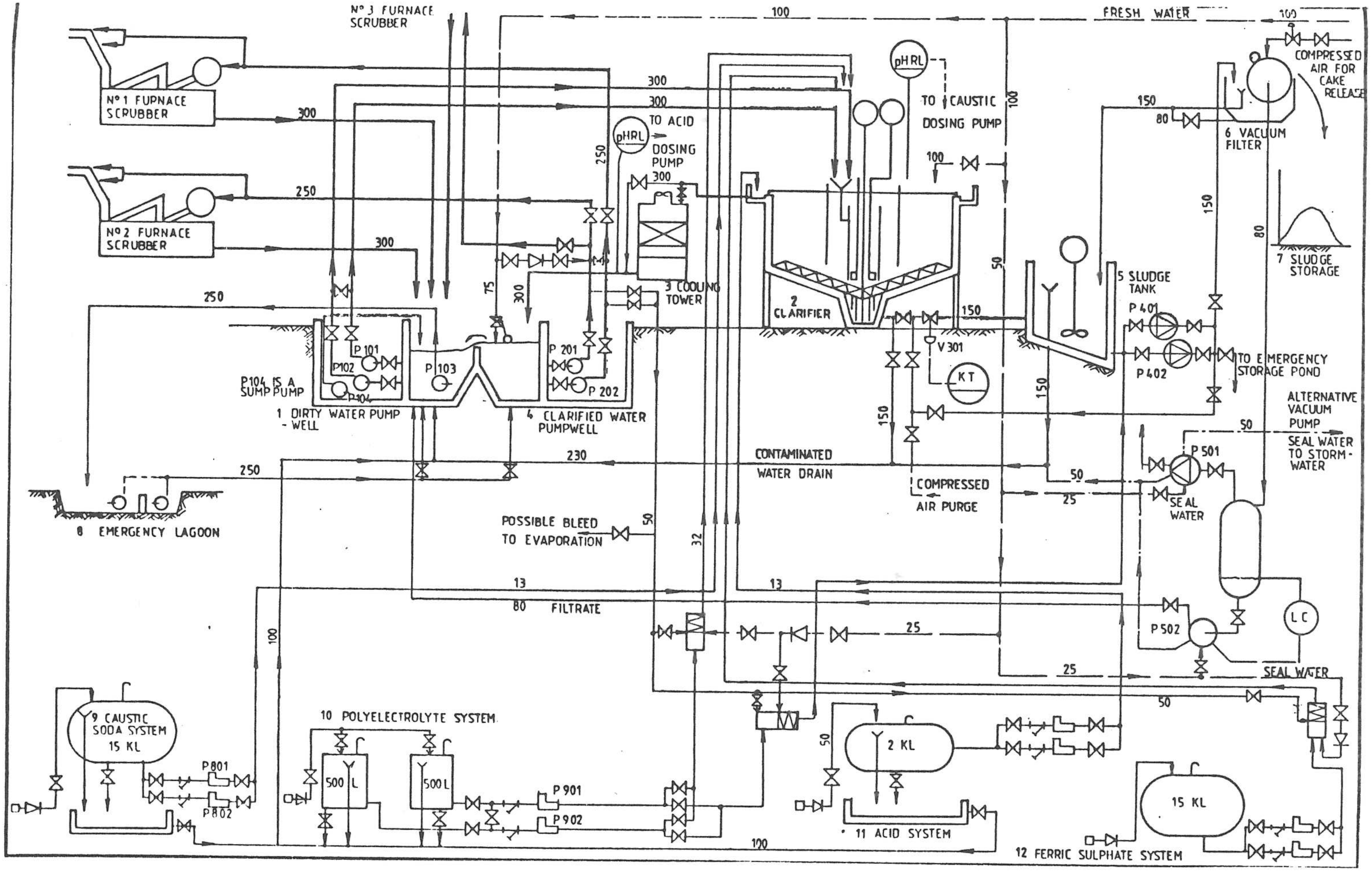

FIGURE 6
HIGH RATE CLARIFIER