THE ESTABLISHMENT OF A 500 000 T/A SINTER PLANT AT SAMANCOR'S MAMATWAN MANGANESE ORE MINE

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SUMMARY

The Kalahari and Postmasburg manganese ore deposits in South Africa contain 13 613 million tonnes of + 20% Mn ore. Much of this is of a low grade, carbonate type. The ore body is up to 45,2m thick in places. Samancor currently operates three manganese ore mines with a combined annual production of 2,4 million tonnes.

During the early seventies, laboratory tests, followed by furnace trials were undertaken to evaluate the suitability of a sintered ore from the Mamatwan mine as compared to the natural ore. These tests produced negative results, but a subsequent investigation and furnace trials involving the use of 25 000t of sintered Mamatwan ore at Samancor's Works at Meyerton indicated that significant improvements could be expected when Mamatwan ore was replaced by Mamatwan sinter.

A location study and the need for an additional furnace as an alternative to the sinter plant indicated that the best solution would be to erect a 500 000 t/a sinter plant at the Mamatwan mine.

Further laboratory tests were conducted to optimise sinter parameters and to enable the technical specifications to be drawn up. The initial plant layout made provision for increasing the capacity at a later stage.

Plant construction and commissioning proceeded as planned and production started on the 25th July, 1988. During the first four months of operation, steady progress has been made in increasing plant output and improving sinter quality. Product grade has been consistent.

Operating results at the alloy works have improved significantly through the use of sinter, and further improvements are expected when all the Mamatwan ore is replaced by Mamatwan sinter.

Future developments include the evaluation of sinter exports, the possibility of an increase in plant capacity, the production of a high grade sinter and the installation of a coal gasification plant as an alternative to the heavy fuel oil used in the ignition furnace of the sinter plant.

INTRODUCTION

Manganese, the 12th most common element in the earth's crust, is a versatile commodity and finds its prime use in steel metallurgy, and is second in importance only to carbon. [1,2]

South Africa is singularly blessed with an abundance of this element. The Kalahari and Postmasburg manganese fields in the remote north western part of the Cape Province in South Africa contain 13 613 000 000t of ore with a minimum manganese content of 20% - this represents some 78% of the total estimated land - based reserves [3,4,5]. Samancor owns by far the greatest share of these reserves. The company currently operates three mines in the Kalahari field viz Wessels, Hotazel and Mamatwan with a combined annual production rate of 2 400 000t. Since the discovery of the Postmasburg field in 1922 and subsequent exploitation of the Kalahari field from 1940 onwards, South Africa has become prominent in manganese mining and smelting.

THE MAMATWAN DEPOSIT

The massive Mamatwan ore body is 45,2m thick at its maximum and is overlain by 45 m on average of overburden comprising of gravel, sand and calcrete. It consists of three zones :

TABLE 1. MAMATWAN ORE BODY

Zone	Thickness (m)	% Mn	Mn/Fe
Upper	19,5	30	3
Middle	19,7	38	>8
Bottom	6	30	5

As Mamatwan is an open cast mine, the upper zone has to be removed in order to mine the middle zone. The upper zone is dumped whilst the bottom zone is left in situ [4].

TABLE II. CHEMICAL ANALYSIS OF MAMATWAN ORE

	Lumpy	Fines
% Mn	37-38	36-37,5
% Fe	4-6	4-6
% SiO_2	4-6	4-6
% CaO	12-16	12-16
% MgO	2,5-5	3-5
% Al_2O_3	0,5	0,8
% Na_2O	0,1	0,1
% K_2O	0,05	0,05
% P (max)	0,05	0,05
$ S (max)	0,08	0,08
% CO_2	15-17	15-17
% H_2O (combined)	1,5	3,0

The ore is hard and brittle. During blasting, crushing and screening, 30% of the ore is reduced to - 6mm. This fraction has a limited use in the production of manganiferous ferro-alloys in either electric or blast furnaces. Over the years, substantial stocks of this fraction accumulated at the Mamatwan mine, located some 850km from the exporting harbour of Port Elizabeth and 650km from Samancor's manganese ferro-alloy Works at Meyerton, where 10 electric furnaces ranging in size from 3,8 to 81 MVA produce more than 500 000t of equivalent HCFeMn at full capacity.

As the fine fraction is unsuitable for Samancor's furnaces an investigation into the most suitable agglomeration process was started in the seventies.

AGGLOMERATION PROCESSES

Apart from the utilization factor, there were other good reasons for agglomerating the fines using pyrometallurgical means :

1. The ore contains up to one fifth by mass of CO_2 and H_2O, both of which are easily driven off during heating. Significant savings in transport cost per manganese unit would result were these components removed.
2. Pyrometallurgical treatment usually results in enhanced properties for smelting in a furnace.

A systematic evaluation of agglomeration processes was undertaken, during which the nodulising, briquetting, pelletising and sintering properties of both Mamatwan and Wessels fines were tested. It became evident that sintering was the best alternative :

1. Feed preparation is relatively cheap and simple - only crushing and screening are involved as opposed to i.a. fine grinding for pelletising.
2. The use of sinter rather than lumpy ore results in savings of electrical energy, electrode consumption and carbon reductant consumption. Furnace operation is safer (less possibility of eruptions), gas evolution is less, higher furnace loads are possible, manganese yield is increased and furnace down times are reduced [6, 7, 8].
3. Sinter does not spall with rapid heating as do some ores; this inert nature of sinter also reduces the risk of eruptions.
4. Sintering was the only process suitable for agglomerating both Mamatwan and Wessels ores.
5. Sintering utilizes "waste products" e.g. coke breeze unsuitable for blast furnace or large electric furnace use and also utilizes coke oven or furnace gas, thus increasing the overall material and energy effiency of the plant.

The next step would be to produce sufficient quantities of sinter for evaluation in the furnaces.

SINTER TRIALS

The first pot tests conducted in 1971 at Iscor's pilot plant indicated that an improvement of 6,6% in strength and 78% in productivity could be obtained relative to iron ore sinters [9]. However, a trial batch of sinter produced inferior results compared to a lumpy ore burden that was used in the production of HCFeMn at Samancor's no 2 furnace at their Meyerton works. The output dropped to 94,4% and the energy consumption increased to 107,9% of the corresponding ore burden values [10].

Despite the negative results, a subsequent study undertaken in 1975 recommended that further, more extensive trials be undertaken, which, if successful, would culminate in the erection of a sinter plant at the Works [11].

Further pot tests were undertaken at the Iscor Pilot Plant during 1975 and 1976 when sinter was produced from a blend of Mamatwan and Wessels ores ranging from 100% to 0% Mamatwan. Both coke breeze and anthracite as solid fuels were evaluated. Excellent results were obtained, particularly with a 7:3 mixture of Mamatwan and Wessels ores and a productivity of more than $30t/m^2/24hrs$ was achieved [12].

This resulted in a large scale test being conducted during 1978 using Iscor's latest Delattre - Levivier sinter strand with on-strand cooling, located at their Newcastle Works when 31 076t Mamatwan - 6mm fines were sintered to produce 24 534t sinter (representing a loss-on-ignition of 16,9% and a handling/moisture loss of 4,2%).

In a programme of systematic evaluation at the Meyerton Works the initial tests were conducted on a 13,2 MVA semi - closed furnace producing HCFeMn. During the tests Mamatwan ore was replaced in 10% steps by Mamatwan sinter. At least one week elapsed between each burden change in order to achieve stable conditions. The programme culminated in the systematic replacement of ore with sinter on the closed 81 MVA furnace at a ratio of 60% sinter, 40% lumpy ore and the following results were achieved [13] :

TABLE III. IMPROVEMENTS WITH 60% SINTER BURDEN

Electrical resistance	(mohm)	: 6% increase
Electrical reactance	(mohm)	: 3% decrease
Energy consumption	(kWh/t)	:15% decrease
Furnace down time	(hrs)	: 1% decrease
Carbon reductant usage	(kg/tFeMn)	:10% decrease

These positive results lead to a detailed feasibility and cost study being undertaken.

FACILITY PLANNING

It was apparent that, since the project was initiated some years previously, significant advances in sinter technology had taken place. A Samancor delegation thus visited major manufacturers and operators of manganese sinter plants throughout the Western World during November 1985. The findings gleaned from this visit were incorporated in an enquiry document and tenders were invited from seven prospective tenderers.

Two tenders from reputable international companies warranted serious consideration. By this time the sinter project had been approved as a project-in-planning and a budget was approved for the planning phase. As with any project, direct comparisons between tenders were difficult and many discussions with the main contenders were necessary.

Although the planning to date had been done on the basis of locating the plant at the Meyerton Works, it became apparent that alternate locations, notably at the Mamatwan mine, also had to be considered. An evaluation of the situation can be summarised as follows :

TABLE IV. PLANT LOCATION STUDY

Works location	Mine location
1. Furnace gas available.	1. Liquid/gaseous fuel to be provided.
2. Breeze coke available in close proximity.	2. Solid fuel not available.
3. Existing infrastructure.	3. Limited supporting infrastructure.
4. Skilled personnel available.	4. Skilled personnel not available.
5. Close to main end user.	5. Far from main end user.
6. Limited export potential.	6. Best location for sinter exports.
7. Higher transportation cost/Mn unit.	7. Lowest transportation cost/Mn unit.

A computer-based financial assessment indicated that the mine location was the optimal solution, despite the fact that not all of the above-mentioned factors were readily quantifiable. A further alternative was the installation of another furnace at the Meyerton Works to achieve the same objective viz a greater FeMn/SiMn output at a lower cost :

TABLE V. SINTER PLANT VS NEW FURNACE

Sinter Plant	New Furnace
1. Sinter benefit to all furances.	1. No improvement in cost, efficiency.
2. By-product utilisation (gas, breeze coke).	2. Generation of by-products.
3. Sinter & alloy export potential.	3. Alloy export potential only
4. Smaller alloy production increase.	4. Big alloy production increase.

The outcome was in favour of the sinter plant.

After alternate agglomeration techniques, alternative plant locations and alternative means of increasing alloy production at reduced costs were evaluated, the conclusions clearly pointed to the installation of a 500 000t/a sinter plant at the mine.

The formal motivation of the plant, the request for the approval of capital for the project and the recommendation of the successful tenderer to the Boards of Samancor and Gencor, the holding company, were facilitated by the extensive data that was available.

An amount of R60 479 000 was approved by the Samancor Board for the project on July 24th, 1986 against a budgeted provision of R60 100 000.

The next phase viz detailed design and plant construction now followed.

PLANT DESIGN AND CONSTRUCTION

Before a detailed design could be completed, it was necessary to optimise key operating parameters, and thus a final series of laboratory sinter pot tests was undertaken.

The tests also aimed at providing small samples for laboratory evaluation by potential customers, as well as determining the sintering characteristics of high grade Mamatwan ore, obtained by means of a dense medium separation process, being evaluated at the time.

In total, 67 pot tests were conducted. Optimum conditions were established as follows [14] :

TABLE VI. OPTIMUM SINTER PARAMETERS

Ore feed size distribution	: 100% -6mm with 20% -1mm
Coke addition rate	: 6% of ore feed at 78% F.C.
Coke size distribution	: 100% -3mm with 50% -0,5mm
Moisture addition rate	: 4,1% of ore feed
Ratio sintering to cooling areas	: 1 to 1
Sinter productivity	: $30 t/m^2/24$ hrs
Sinter cold strength (ISO 3271)	: >75% +6,35mm
Sinter abrasion index (ISO 3271)	: 4,2% -0,5mm
Suction during sintering	: 1 300mm H_2O
Suction during cooling	: 1 100mm H_2O

The relationship between suction and productivity was determined for a given ore particle size range as :

$$P = 0{,}0355S - 1{,}48$$

where S = suction in mm H_2O
P = productivity as $t/m^2/24h$

The relation between mean particle size and productivity was determined at constant suction during sintering as :

$$P = 38{,}18Dp - 58{,}32$$

where Dp = mean particle diameter in mm

In addition, the mineralogical composition of the Mamatwan ore and sinter was determined using incident light microscopy, X-ray diffraction analysis and electron microprobe analysis [15] :

TABLE VII. MINERALOGICAL COMPOSITION : ORE AND SINTER

	Ore	Sinter
Braunite	: $Mn^{2+} Mn_6^{3+} SiO_{12}$	Manganosite : MnO
Kutnahorite	: $Ca(Mn,Mg,Fe^{2+})CO_3)_2$	Hausmannite : Mn_3O_4
Calcite	: $CaCO_3$	Calcium silicates
Hematite	: Fe_2O_3	

Calcium silicates act as a binder material for the manganese oxides. The binder is amorphous (glass). This gives an indication of the inert nature of sinter.

The technical specifications of the plant were derived from the sintering parameters. An important criterion was that the plant should incorporate the maximum local content.

TABLE VIII. TECHNICAL SPECIFICATIONS

Type	: On-strand cooling
Design capacity	: 500 000 t/a
Duty	: 24 hours continuous operation 330 days/a
Strand length	: 41,5m
Strand width	: 2,44m
Strand speed	: Infinitely variable 0-2m/min
Grate area	
- Sintering	: 53,6 m2
- Neutral	: 17,9 m2
- Cooling	: 29,8 m2
- Total	: 101,3
Bed depth	: 450mm
Max. ignition hood temp.	: 1 300 °C
Productivity	: $28{,}3 t/m^2/24$ hrs
Fuel rate	: 120 MJ/min
Air pollution control	: Electrostatic precipitator for sinter section. Cyclones for cooling section. Bag filter for materials handling and room dedusting.
Fan capacity	: 250 000 A m^3/hr (sintering) 300 000 A m^3/hr (cooling)

The possibility of increasing the plant capacity at a later date was catered for in the initial layout by providing for the installation of an off-strand circular cooler. In addition, at the outset certain items of the plant were sized for the ultimate capacity; these included the gas ducts, the raw material storage bins and conveyors. This ensured that the incremental cost of significantly increasing the capacity would be minor by comparison to the initial capital outlay.

Careful thought was given to tying the new facility into the existing plant, as well as to planning the integration of the new plant with minimal disruption of the normal mining operation.

Provision was made for sintering both Wessels and Mamatwan fine ores.

Impact-type crushers were installed to provide ample feed to the sinter plant, and as electric furnace gas was not available, a storage and reticulation system for heavy fuel oil (with diesel oil as a standby) had to be installed.

Despite the remote location of the plant, it was decided to install a state-of-the art PLC - based instrumentation and control system, whilst also providing for a comprehensive management information system with data logging facilities and trend displays. The system software and patented keyboard design were developed and produced locally.

Important considerations were simplicity of design, robustness of construction and ease of operation and maintenance.

Figure 1 is an illustration of the general plant layout. Figure 2 depicts the flow diagram while figure 3 gives a view on two sections through the sinter plant.

CONSTRUCTION

A bar chart and critical path analysis indicated that a twenty four month period from start to finish was required. A dedicated Samancor project team was formed which worked in close collaboration with the main contractors. Strict financial control was exercised. Monthly progress reports were submitted to the management committee.

Progress was carefully monitored against the critical path, and no delays which would have an effect on the commissioning date were experienced, despite minor problems occurring at times.

Key personnel were recruited and employed and formal training of operating and maintenance staff was initiated, as few of the sinter staff had the relevant experience. However, all concerned were enthused by the new project and skills were quickly developed. During the subsequent commissioning stage, hands-on training was provided when plant personnel worked alongside the commissioning engineers.

COMMISSIONING

Very few problems were experienced during the commissioning of the plant in August 1988 and no changes to the operating parameters as determined by the laboratory pot tests were necessary. Material spillages at transfer points and minor electrical faults occurred during this period, but these were soon rectified.

The next phase consisted of the performance run when the operational guarantees as specified in the enquiry document were to be met. The acceptance tests were performed during a continuous run of seven days and involved the imposition of penalties were these results not achieved. The tests involved the following :

1. A graded sinter production rate of 1515 t/d over the test period.
2. An ISO Tumbler Index of >70% +6,35mm on the graded sinter.
3. An energy input to the ignition hood of not more than 120 MJ/t at the rated output and with 450mm bed depth.
4. An electrical energy consumption of not more than 26 kWh/t of graded sinter for the equipment within the scope of supply of the main contractor.
5. Dust emission from the waste gas cleaning units of not more than 100 mg/Nm^3 of exhaust gas.
6. An average sinter temperature of not more than 120 C at the exit of the on-strand cooling zone.
7. A dry coke rate of not more than 87 kg/t of graded sinter at the rated output and with 450mm bed depth. The nett calorific value of the dry coke supplied during the acceptance tests should not be less than 28 GJ/t.

All of the above requirements were met during the acceptance test period and the plant was officially handed over to Samancor. Plant operation started on the 25th July, 1988.

PLANT OPERATION

An important function was the official opening of the plant which took place on Tuesday, 27th September, 1988. For this occasion, Samancor invited 44 overseas visitors as well as a host of local guests and dignitaries to attend the event.

After these formalities, it now remained firstly to achieve steady state conditions and thereafter to optimise the operation of the plant systematically, particularly in the light of potential exports of sinter where physical quality would be of prime importance.

The performance of the plant since start-up is tabulated below.

TABLE IX. PLANT PERFORMANCE

	Aug	Sept	Oct	Nov
Prodn (t/m)	16487	34508	37370	42722
Prodn (t/d)	610	1113	1246	1424
Annual (t/a)	222650	40624545	4790	519784
Operating time (%)	45,2	70,5	71,1	80,3
Fuel oil consumpt. (MJ/t)	124,8	122,2	96,9	96,2
Coke consumpt. @ 28 MJ/kg (kg/t)	94,25	99,3	91,47	84,57
Strand speed (m/min)	1,10	1,09	1,02	1,02
Sinter analysis				
% Mn	44,6	45,21	44,84	44,75
% Fe	5,90	5,99	5,98	5,89
Mn/Fe	7,55	7,55	7,50	7,60
% SiO_2	7,3	6,39	7,31	6,66
% CaO	17,2	16,59	16,72	17,34
Tumbler index	-	78,08	80,22	81,87

During the first four months of operation, frequent stoppages were necessary for adjustments and minor modification. The plant was also shut down for planned maintenance. However, the operating times have increased progressively.

The monthly production has consistently increased over the four months and the rated capacity was exceeded during November, despite an operating time of 80,3%.

The specific fuel oil consumption has decreased consistently and is now well below the guaranteed value.

Coke consumption has also shown a decrease and, correcting for the energy value, is also below the guaranteed limit.

Total energy consumption is affected by plant stoppages and it is anticipated that further reductions will be possible at the rated operating time of 90,4%. (330 days/annum)

The chemical analysis of the sinter has been very consistent with the manganese content always in excess of the minimum value of 44,0% Mn.

Significant improvements have been made to the physical strength of the sinter, as reflected in the ISO Tumbler Index. This very important index will be improved even further and fundamental tests are being conducted to quantify the effect of the various operating parameters on the strength of the sinter.

The overall performance of the plant and quality of the sinter has exceeded expectations with further improvements yet to come.

FURNACE RESULTS

At the time of writing, the total output of the sinter plant has been supplied to Samancor's alloy works at Meyerton. As with the previous programme, sinter was first tested on the smaller furnaces before being used on the 75 and 81 MVA closed furnaces. Results to date have been most encouraging. A summary of indexed results from M11 furnace (75 MVA) for November 1988 producing HCFeMn with discard slag from a sinter burden is given below. These results are compared with typical year- to-date results from a Mamatwan ore burden.

TABLE X. M11 FURNACE RESULTS

		Ore Burden	Sinter Burden
Saleable production	(t/m)	100	118,7
Energy consumption	(kWh/t)	100	84,2
Furnace load	(MW)	100	101,8
Electrical resistance	(mohm)	100	102,4
Operating time	(%)	100	100,7
Mn recovery	(%)	100	105,2
Electrode consumption	(kg/t)	100	90,2
Reductant consumption	(kgFC/t)	100	95,3
Ore Burden :	(%)		
Wessels ore		56,4	58,0
Mamatwan ore		43,6	6,0
Mamatwan sinter		-	36,0

Further improvements are likely when all the Mamatwan ore has been substituted by Mamatwan sinter.

FUTURE

Exports

Great interest has been shown by prospective users locally and abroad. It is anticipated that the first trial export shipment will be made before the end of 1988 and, depending on availability, other shipments will follow during 1989. Size degradation during transport as well as production performance will be carfully monitored.

Plant Capacity

Depending on the interest from Samancor's own works and from users elsewhere, detailed studies will be undertaken to increase plant capacity by the installation of a circular, off-strand cooler, thereby utilising the full area of the strand for sintering only.

High Grade Sinter

In parallel to the sinter programme, Samancor also undertook tests to upgrade the Mamatwan ore from 37/38% Mn to 43/44% Mn by means of Dense Medium Separation (DMS). Laboratory tests were most encouraging and resulted in the erection of a 20 t/h pilot plant at the Mamatwan mine. During a one-year trial period, extensive tests were conducted and the process variables were optimized. Capital for a full scale plant to produce 580 000 t/a of upgraded ore was approved during May 1988 and the contract was awarded in August 1988. Construction has started and project completion is scheduled for September 1989, after which time a sinter of the following composition will be produced as compared to the standard grade material :

TABLE XI. SINTER ANALYSIS

	Standard Grade	High Grade
% Mn	44,0	50,6
% Fe	6,0	5,9
% SiO_2	6,8	5,4
% Al_2O_3	0,95	0,90
% CaO	17,2	13,4
% MgO	2,8	2,8
% Na_2O	0,35	0,34
% K_2O	0,20	0,18
% P	0,03	0,03
% S	0,03	0,03

Coal Gasification

To reduce the cost of coke breeze and heavy fuel oil, Samancor is currently evaluating coal gasification in a fluidised bed gasifier to supply coal gas as a replacement for the heavy fuel oil. The residual char will partly replace the coke breeze. Laboratory tests have already been completed and a financial evaluation is being made.

CONCLUSION

The initial indications are that the project has been justified in terms of benefits in the production of HCFeMn and SiMn at Samancor's works. The reaction from other users will be taken into consideration when deciding on whether and when to increase the capacity of the plant.

ACKNOWLEDGEMENTS

I wish to thank Samancor Ltd for permission to publish this paper. Thanks are due to my colleagues for their assistance and to Mrs Liebenberg for typing the manuscript. I also wish to thank the staff at Iscor's Pilot Plant for their support with the laboratory pot tests.

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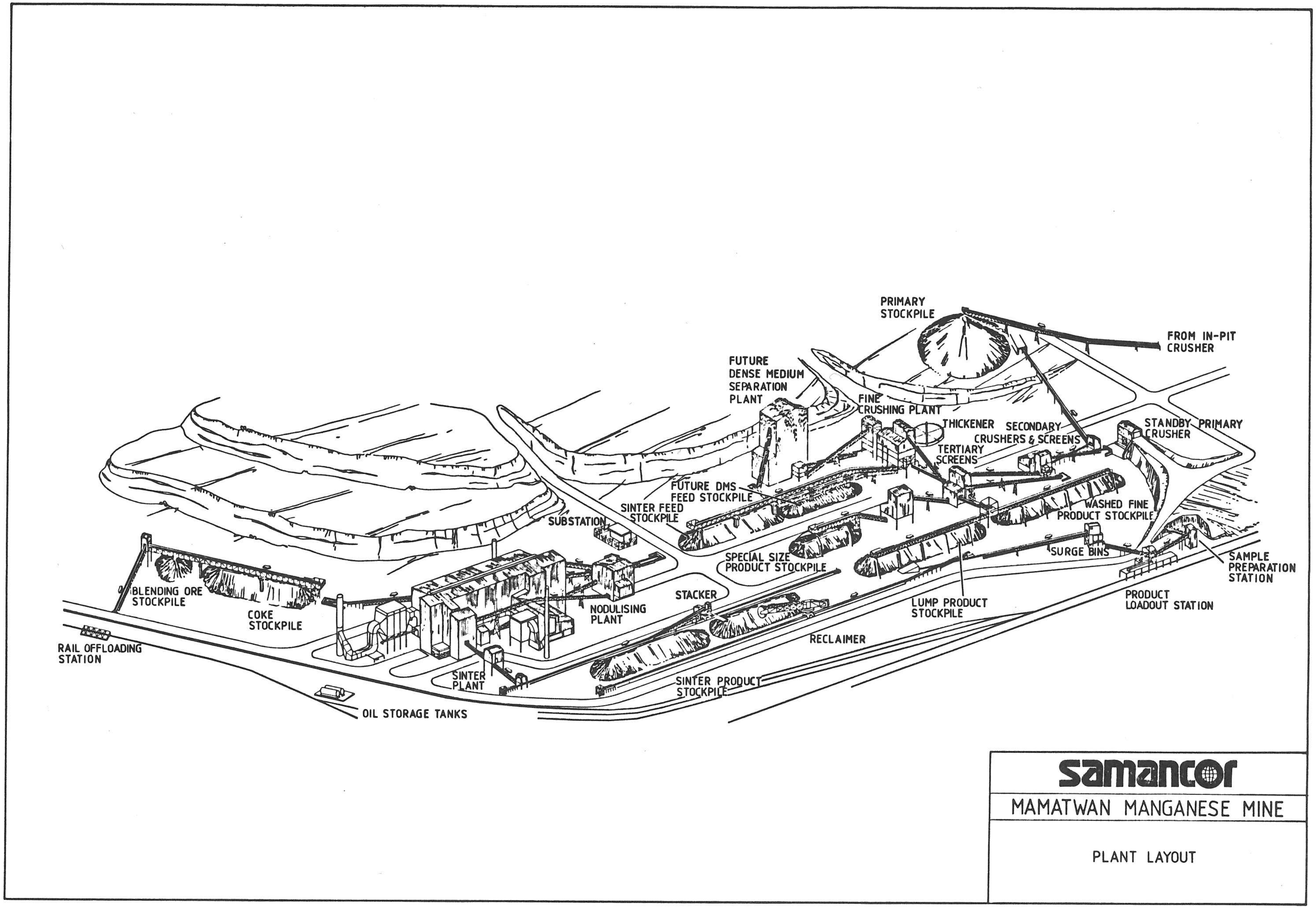

Fig. 1. General plant layout

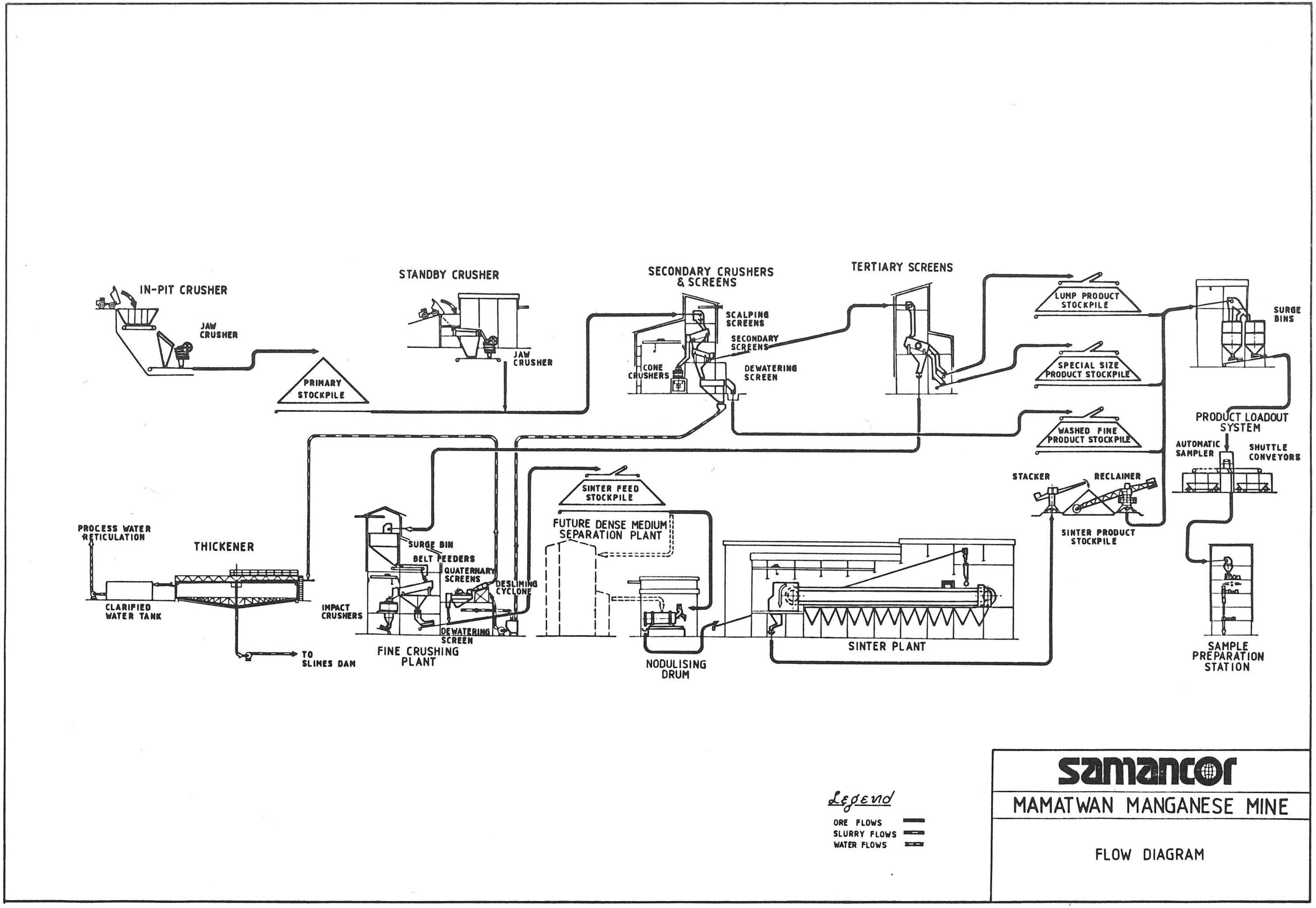

Fig. 2. Sinter Plant flow diagram

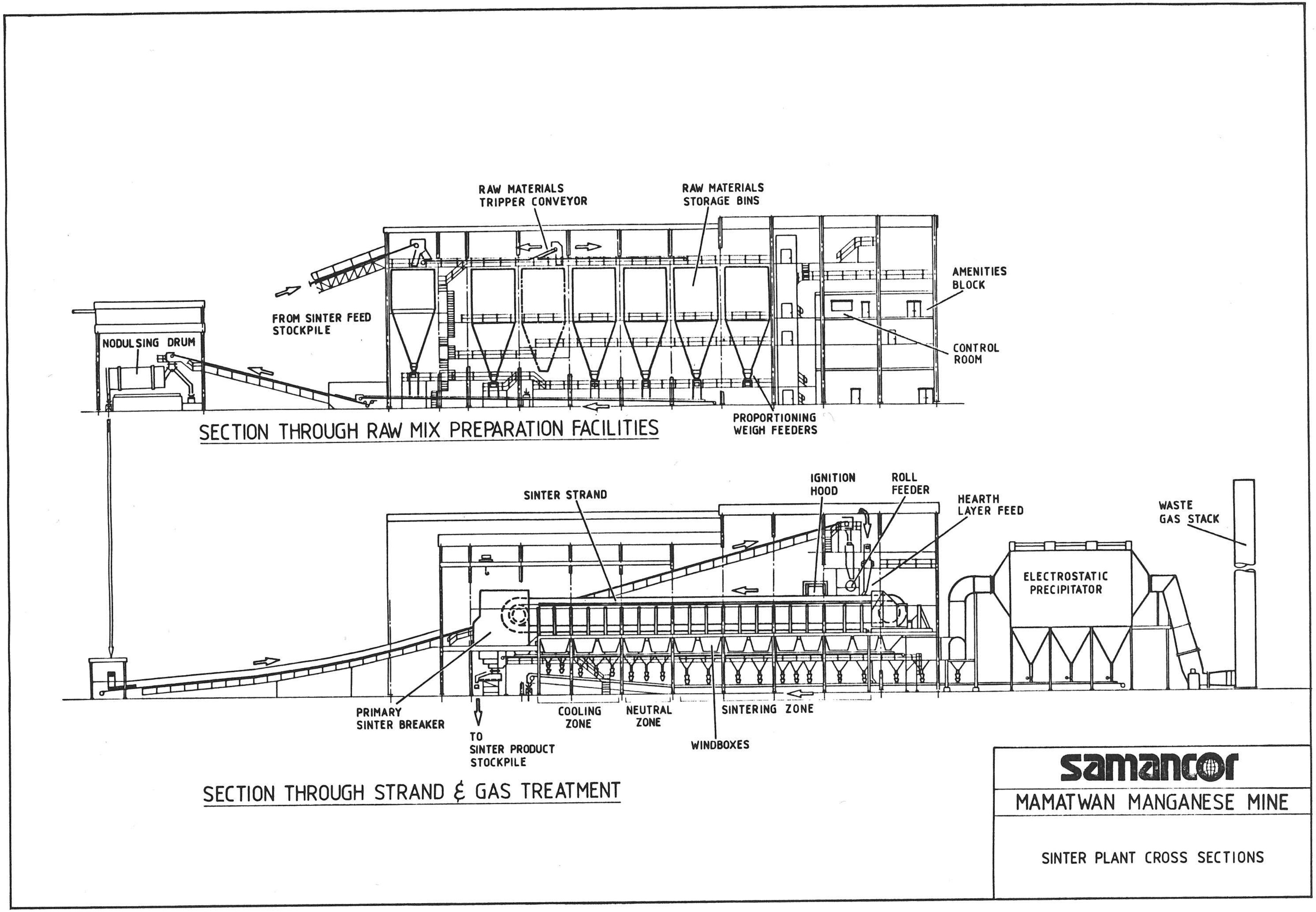

Fig. 3. Sinter Plant cross sections