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A Case Study of the Production of High-grade Manganese Sinter from Low-grade Mamatwan Manganese Ore

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South Africa has 13,6 billion tons of manganese ore with a manganese content of more than 20 per cent, and is a major producer of manganese ore and ferroalloys. Owing to an increasing need to compete in the high-grade manganese market and to increasing production and transport costs, investigations into the possibility of beneficiating manganese ores by means of an agglomeration process were started in the 1970's. These investigations resulted in the erection of a 500 kt/a sinter plant at Samancor's Mamatwan manganese mine in 1987. This plant initially produced a 44 per cent manganese sinter from a feed of 38 per cent carbonaceous manganese ore. The use of the 44 per cent manganese sinter resulted in large savings in transport cost per manganese unit, as well as a decreased energy consumption (15 per cent) and an increased manganese throughput in the smelting furnaces producing ferromanganese alloys.

Continued investigations into beneficiation processes resulted in successful pilot-plant tests on the dense-medium separation of manganese ores using a ferrosilicon medium.This process was able to upgrade the manganese ore economically from 38 to 42 per cent manganese. At the end of 1989 a production dense-medium separation plant was commissioned, producing a 41,5 per cent manganese feedstock for consumption in the sinter plant. With the use of this material, the sinter plant produced a sinter of 48 per cent manganese.

The smelting furnaces showed a further increase in productivity: the energy consumption was decreased by 14,7 per cent, and production was improved by 17,4 per cent while producing 78 per cent high-carbon ferromanganese, as opposed to 76 per cent high-carbon ferromanganese.

The upgraded material produced by the dense-medium separation plant contained less carbonate and fine material than the previously used Mamatwan ore, reducing the sinter-plant productivity by 10 per cent. Tests are being conducted on the use of quasi-granulation technology to restore the productivity to its previous levels.

Possible future developments include spiral concentration of the fine material to enhance the granulation of the sinter mixture without diluting the feed grade, the production of a sinter containing more than 50 per cent manganese, and the application of infrared technology to pre-heat and ignite the sinter bed.

Introduction

Manganese is one of the most abundant elements in the earth's crust, and was discovered in South Africa at Black Rock by Dr A. W. Rodgers in 1907. Manganese was initially mined at Hout Bay, near Cape Town, and in 1917 small quantities were exported[1]. The major deposits, however, lie in the northern Cape Province in the Postmasburg area, where mining first started in 1922, and in the Kalahari manganese field. In 1950 prospecting started in the Kalahari manganese field, and mining commenced at Smartt in 1954.

The major producers of South Africa's manganese output are two companies, Samancor (operating two mines) and Associated Manganese Ltd (operating four mines). The production of ferromanganese in South Africa started in 1938 at Newcastle in a disused iron blast furnace operated by Amcor till 1965[2]. In 1939, expansions of Amcor's production resulted from the building of a new electric-furnace plant at Vereeniging. Owing to an increased demand for ferro-alloys, the need for extra capacity led to the opening of a new production facility at Meyerton in 1951. This operation is now owned by Samancor following a merger between Amcor and S.A. Manganese[2]. In 1988 the Republic of South Africa was the largest producer of ferromanganese in the world (694,6 kt) and the largest exporter of manganese ore[1] (2735 kt).

Samancor, a group of companies within Genmin, produces manganese ores, ferromanganese and silicomanganese alloys, electrolytically produced manganese and manganese dioxide, chromium ores, ferrochromium alloys, silicon metal, silica sands, phosphates, and ferrosilicon medium for use in heavy-medium separation.

Locality and Reserves

The Kalahari Manganese Field

South Africa has the largest manganese-ore reserves in the world, with 13,6 billion tons of ore with a manganese content greater than 20 per cent, but this is not always of the highest grade available on the world market[1,3]. The main Kalahari field is located between latitudes 27° and 27° 30' S and close to longitude 23° E. It extends continuously in a northwesterly direction from Mamatwan for a distance of 34 km to the Wessels and Black Rock mines in the north. The thickness varies between 0 and 45 m at depths of 45 to 400 m and at a 5° westerly dip. The width of the field varies between 5 and 20 km, and the total area underlain by manganese is approximately 230 000 ha.

The Mamatwan Deposit

Three subdisivions are distinguished in the Mamatwan manganese body. The material overlying the manganese comprises gravels, sand, and calcrete. The ore is extracted by opencast mining, necessitating the removal of the overburden and the upper zone of the manganese body before the economic central zone can be removed. The lower uneconomic zone is not exploited, and is left as the mining footwall. The ore consists of banded, very fine-grained braunite, kutnahorite, and lutite containing concretionary ovoids, laminae, and lenticles of manganese calcites with which hausmannite is commonly associated. Subordinate amounts of hematite, jacobsite, and rhodochrosite are also present[4].

Table I lists the ore and the gangue minerals, together with their compositions and the extent to which they occur in the mined ore. The high carbonate content makes this ore virtually self-fluxing, and the comparatively low iron content (4 to 6 per cent) results in the ore having a manganese-to-iron ratio suitable for the production of high-carbon manganese alloys. The low phosphorus (<0,05 per cent) and aluminium (<1 per cent) contents are of major importance in the production of high-quality alloys and the achievement of furnace efficiency[6].

TABLE I
CHEMICAL COMPOSITION AND DENSITIES OF THE MAIN MINERALS[5]

Mineral	Formula	Mn content %	Density g/cm^3	Occurrence mass %
Braunite	$Mn^{2+}Mn^{3+}{}_6SiO_{12}$	53,1	4,7	30 – 50
Hausmannite	Mn_3O_4	72,0	4,7	2 – 20
Cryptomelane	KMn_8O_{16}	59,8	4,3	2 – 8
Manganite	MnOOH	62,5	4,3 – 4,4	Trace
Jacobsite	$MnFe_2O_4$	23,8	4,7	2 – 3
Hematite	Fe_2O_3	0	5,2	7 – 10
Kutnahorite	$Ca(Mn, Mg)(CO_3)_2$	23,0	3,8	18 – 25
Calcite	$CaCO_3$	0	2,8	2 – 15

Preparation of the Ore

Up to 1987, the process consisted of open-cast mining followed by various stages of crushing and screening before the ore was dispatched to the consumer. With the exception of small uses in the uranium, battery, chemical, and agricultural industries, sales of manganese ore are largely dependent on steel production. The use of manganese dropped steadily from 40 to 34 kg of ore per ton of steel from 1950 to 1985, although this was expected to be reversed by the use of the optimizing refining process (ORP), which uses manganese ore at the cost of ferromanganese alloys[2]. This, however, has not yet been realized, mostly owing to the high costs involved in the ORP. Increasing transport costs, coupled with an international demand for high-grade ore, are encouraging producers to investigate means of beneficiating manganese ores. Australia and Brazil are both examples of countries competing in the market for sinter containing more than 50 per cent manganese[7].

Despite Samancor's large ore reserves, high-grade ores containing more than 48 per cent manganese comprise a relatively small fraction, which could be supplemented by an upgraded sinter product from dense-medium separation. These factors resulted in the establishment of a 500 kt/a sinter plant at the Mamatwan mine in 1987, followed by a dense-medium separation plant in 1989.

Description of the Process at Mamatwan

Figure 1 is a schematic flow diagram of the process.

Crushing and Screening

Primary crushing and screening are done in the pit by means of a vibrating grizzly and a jaw crusher. The ore is reduced to –150 mm, and the crushed ore is conveyed along a belt system 2 km long to the primary stockpile. A standby jaw crusher in the plant is used in the event of breakdowns of the inpit crusher or the conveying system.

Secondary screening takes place in two parallel systems comprising scalping screens, cone crushers, double-deck sizing screens, a horizontal dewatering screen, and a degritting cyclone circuit. A washed +6 mm –75 mm lumpy fraction, a –6 mm +200 µm dewarted fines product, and a –200 µm slurry are produced in this section.

The tertiary screening circuit consists of three parallel double-deck sizing screens to separate the +6 mm –75 mm lumpy fraction, which is fed from the secondary crushing and screening section, into a +6 mm –25 mm fraction and a +25 mm –75 mm fraction. The largest part of the +6 mm –25 mm product is consumed by the quaternary section, the rest being sold as ore. All the +25 mm –75 mm product is sold as lumpy ore.

The quaternary crushing and screening section comprises four Barmac vertical-shaft impact crushers, each fed by a separate sizing screen, and produces a –19 mm product from the +6 mm –25 mm fraction. This product makes up the feedstock for dense-*medium separation*.

Desliming and Thickening

Slurry from the degritting cyclone overflow is dewatered in a single thickener before being pumped at a relative density of 1,8 g.cm^{-3} to a slimes dam situated approximately 1 km from the plant.

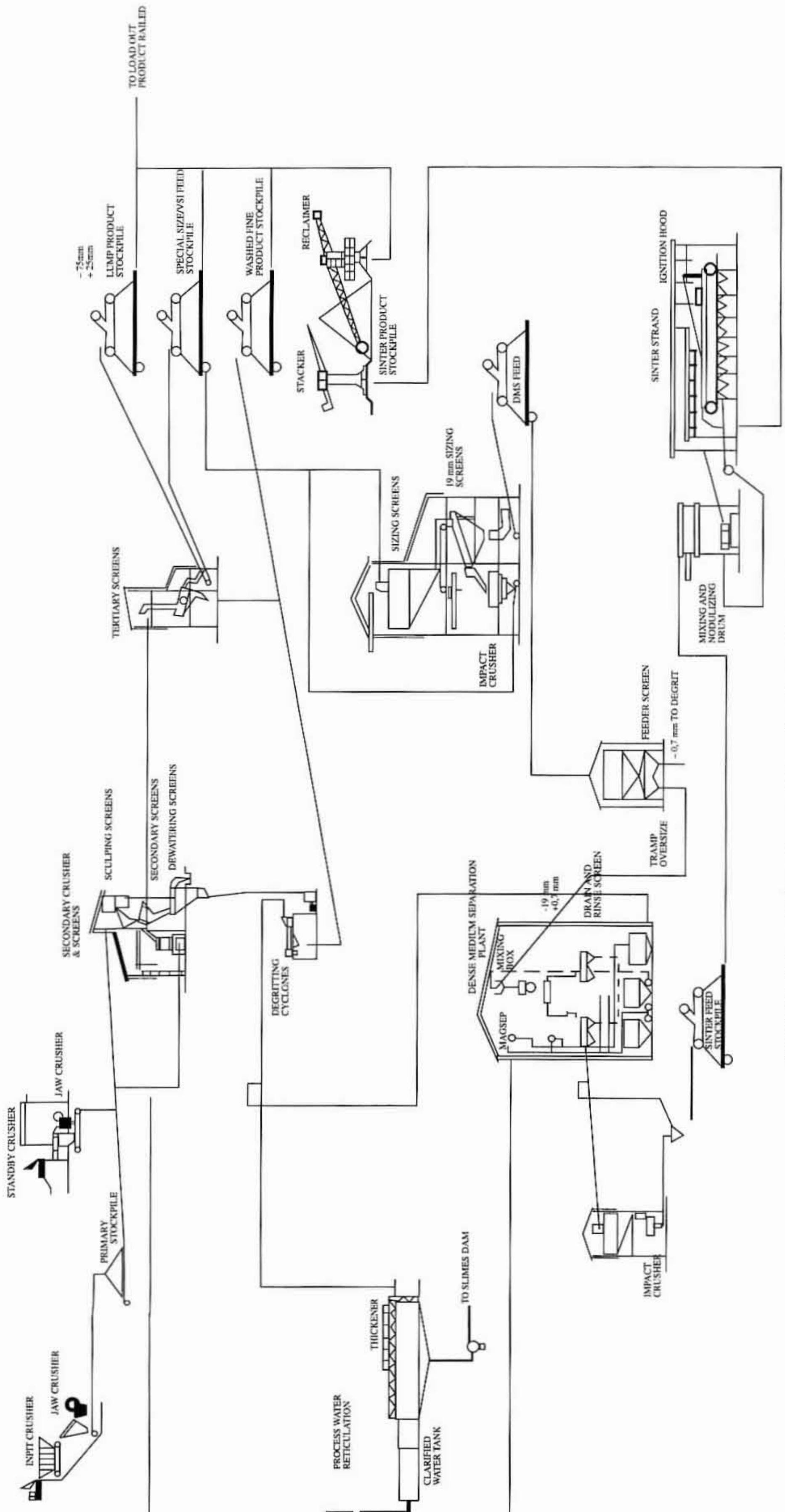

FIGURE 1. Schematic flow diagram of the surface plant at Mamatwan

Dense-medium Separation

The quaternary crushing product contains 12 to 16 per cent –0,7 mm material by mass, which is removed by wet screening in a feed-preparation circuit. The +0,7 mm material (at 37,0 to 37,5 per cent manganese) is fed to the dense-medium separation modules, and then mixed with a ferrosilicon medium at a relative density of approximately 3,3 to 3,4 and separated in four dense-medium cyclones. The concentrate (41,5 to 42,0 per cent manganese) is crushed by means of two Barmac vertical-impact crushers in circuit with a sizing screen to 96 per cent –6 mm, and is then stockpiled as sinter-plant feed. The –0,7 mm grit and the float product from the dense-medium separation, containing 32 to 33 per cent manganese, are discarded as waste. Plant specifications are given in Table II.

Sintering

Manganese ore and coke breeze are mixed with return sinter and dust from the pollution-protection units, and are mixed and nodulized in a horizontal drum and loaded onto the sinter strand. An oil-fired ignition hood ignites the surface of the sinter bed to start the sintering. On-strand cooling is aided by mist sprays at the end of the cooling section, and the cake is off-loaded into a rotating sinter breaker. Screening returns the –6 mm sinter for recycling, separates a +6 mm –15 mm hearth-layer fraction, and routes the final sinter to the final-sinter stockpile at more than 48 per cent manganese.

Reasons for the Adoption of Sintering

In order to maintain a competitive edge and reduce cost increases, an increase in the productivity of the mine by the optimization of its use of resources is important. Because manganese has been used in steelmaking for so long and such vast quantities are available, not enough consideration has been given to the beneficiation of the resources in the past. However, this has changed, and proof of this can be found in some of the advantages of sintering, which are given below[3].

- Greater utilization of fine ore, largely unwanted in the production of ferromanganese and silicomanganese, that has accumulated at the mines.
- Mass reduction resulting from the high carbon dioxide content of the ore, which is easily driven off by heating, leading to a significant saving in transport costs per manganese unit.
- Enhanced properties for smelting in a furnace:
  - increased furnace production and higher furnace loads
  - lower consumption of reductants
  - increased recovery of manganese
  - reduced and better-controlled emission of gas, resulting in fewer furnace eruptions and lower maintenance costs.
- Relatively cheap and simple preparation of feed for sintering since only crushing and screening are required, as opposed to the fine grinding required for pelletization.
- Utilization of waste products such as coke breeze that are unsuitable for blast and large electric furnaces, resulting in an increase in the overall raw-material and energy efficiency of the plant.

Establishment of a Sinter Plant at Mamatwan

Initial testwork on the sintering of manganese ore started in 1971. The first pot tests showed that improvements with regard to strength (+6,6 per cent) and productivity (+78 per cent) could be obtained relative to iron ores[3].

Most ferromanganese and silicomanganese alloys are produced in electric-arc furnaces, where electricity is used to smelt the ore and to provide the heat for the reduction reaction. Electricity is the largest single cost component in the production of manganese alloys. Ferromanganese[2] requires 2800 kWh/t, and silicomanganese[2] 4800 kWh/t. Any savings in energy in the production of these alloys are therefore of significance in the total production costs.

More pot tests were undertaken in order to optimize the key operating parameters, to provide small samples for laboratory evaluation by potential customers, and to determine the sintering characteristics of high-grade ore produced by a dense-medium pilot plant. Since the price of manganese ores (and sinter) is expressed in terms of manganese units and transport costs are paid per ton, the savings in transport costs would be increased with an increase in the concentration of manganese in the sinter provided that increases in the production costs did not exceed this gain. The test results indicated that a further upgrading by sintering would be possible if the concentrate from dense-medium separation were used as feed stock[3].

TABLE II
DESIGN SPECIFICATIONS OF THE DENSE-MEDIUM SEPARATION PLANT

Density of magnetic-separator conct.		3,4 – 3,7
Plant availability		6-day week, 77%/day
Number of modules		2
Feed rate (to feed preparation)		280 t/h (dry)
Surface moisture		4%
Maximum particle size		15 mm
Maximum –0,7 mm		14%
Maximum –2,83 mm		60%
Bulk density		2,2 t/m^3
Solid density		3,5 t/m^3
Cyclones:	Number/module	2
	Type	420 mm dia. DSM
Feed pressure:	Gravity head	10,5 m
	Cyclone diameters	25 diameters
Targeted Epm at normal conditions		0,06
Normal circulating density		3,4
Normal cut-point		4,0
Normal differential (feed: underflow)		0,7
Maximum cut-point		4,3
Maximum circulating density		3,7
Medium composition		Samancor cyclone 60
Centrifugal densifiers:	Number/module	6
	Feed capacity (r.d. = 1)	32 m^3/h
	Feed pressure	12 m head
	Overdense r.d.	4,2
	Dilute r.d.	1,1 – 1,2

Heavy-medium Separation of Mamatwan Ore

Separation Principle

Table I lists the various minerals in the ore and their densities. These densities are only theoretical values, which can vary considerably in the deposit. The ore is fine-grained and carbonate-rich, and the manganese-bearing minerals are characterized by a dark-brown or dull-greyish colour. The macro- and micro-banding of the ore is accentuated by lamellae of carbonate minerals within the ore. Ovoids (ellipsoidal structures) are typical and contain mostly carbonates, which give the ore a spotty appearance. Only the carbonate minerals, calcite and kutnahorite, have densities significantly different from those of the other minerals.

Other factors that are critical to the mechanism of separation are the fine-grained texture, the intimate intergrowth, and the minute grain size of the ore minerals and their bulk density, making it impossible to separate mono-mineralic phases[4]. Those ore minerals which are closely associated with the carbonates will report to the lighter float fraction owing to their small size and intimate intergrowth. The bulk density of such composite minerals is lighter than the relative density of the bulk ore mineral.

Optical and X-ray-diffraction studies showed that braunite and hausmannite are the major minerals contributing to the enhanced manganese content of the sink fraction. This is illustrated in Figure 2. The manganese-to-iron ratio of the sink fraction is favourably increased in that the hematite and jacobsite, being closely associated with the carbonates, report to the float fraction. The dense-medium separation thus separates the braunite- and hausmannite-rich oxide particles from the kutnahorite- and calcite-rich particles.

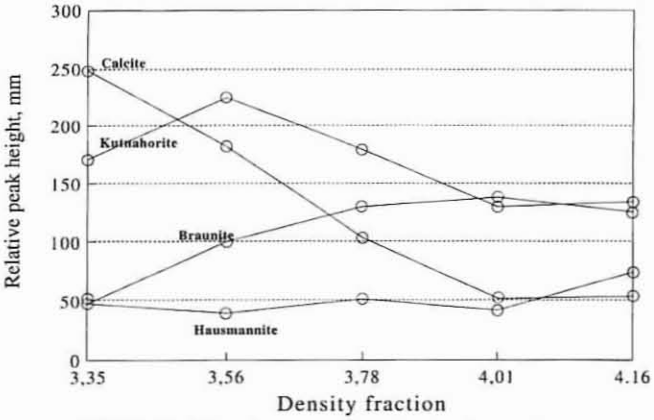

FIGURE 2. Mineral content versus density of separation

Owing to the variance in texture and relative concentrations of the various minerals, there are drastic differences in recovery between ore from different zones in the mine. Under normal operating conditions, no correlation exists between the feed grade (percentage manganese) and the mass recovered as a concentrated product, since the different mineralogical zones are mined selectively according to manganese content.

Tests on Dense-medium Separation

Investigations into the dense-medium separation of Mamatwan ore started at Mintek in 1985. The results from bench-scale tests on a cyclone pilot plant of 150 mm diameter indicated the possibility of the economic upgrading of Mamatwan ore from 37 per cent manganese to between 42 and 44 per cent manganese. After limited testwork at Iscor's pilot plant in Pretoria, a 20 t/h pilot plant was erected on the mine. Tests carried out on this plant were successfully completed at the end of 1987. The production plant was commissioned during November 1989. The design specifications of the plant are listed in Table II.

Typical production figures are given in Table III, indicating the average mass recovery, as well as improvements in the chemical grade.

TABLE III
DENSE-MEDIUM SEPARATION, 1990

1990	Jul.	Aug.	Sep.	Oct.	Average
Production, t/m	52 455	53 197	59 490	53 175	54 579
Production rate, t/h	116,9	116,6	117,5	120,0	117,8
Operating time, %	72,0	73,1	78,1	71,0	73,6
Mass recovered to conct., %	45,0	45,1	45,2	45,3	45,15
FeSi consumption, g/t of feed	177	165	158	168	167
Feed, % Mn	37,8	37,6	37,6	37,8	37,7
% Fe	4,3	4,3	4,3	4,3	4,3
Mn/Fe	8,8	8,7	8,8	8,8	8,8
Product: % Mn	42,1	41,9	41,8	41,7	41,9
% Fe	4,0	4,1	4,1	4,1	4,1
Mn/Fe	10,5	10,2	10,2	10,2	10,3

Production of High-grade Sinter

As soon as the new dense-medium separation plant had been commissioned to a reliable production stage, the sinter feedstock was changed from Mamatwan type ore to concentrate from dense-medium separation. Production results for the sinter plant when this material was used are shown in Table IV.

TABLE IV
PRODUCTION RESULTS FOR 1990 WHEN DENSE-MEDIUM CONCENTRATE WAS USED AS SINTER FEEDSTOCK

	Jul.	Aug.	Sep.	Oct.	Average
Production, t/m	44 128	44 850	48 805	47 582	46 341
Production rate, t/h	66,99	66,60	69,47	70,70	68,44
Productivity, $t/m^2/day$	27,00	26,85	28,00	28,50	27,60
Operating time, %	91,49	90,52	94,43	93,48	92,48
Ore consumption, t/t of sinter	1,17	1,16	1,18	1,18	1,17
Product/ore ratio	0,86	0,86	0,85	0,85	0,85
Coke consumption, kg/t of sinter	104,0	108,1	106,9	106,6	106,4
Oil consumption, kg/t of sinter	2,73	2,5	2,64	2,37	2,56
Return fines, kg/t of sinter	444	445	433	388	428
Power consumption, kWh/t of sinter	34,17	34,40	31,64	31,34	32,89
Suction, mm H_2O: Sintering	773	749	775	741	760
Cooling	607	556	661	661	654
Bedspeed, m/min	1,00	1,00	1,00	1,00	1,00
Sinter: % Mn	48,35	48,14	48,00	48,39	48,22
% Fe	5,03	5,13	5,15	5,18	5,12
Tumble index (+6,3 mm)	80,23	80,41	79,89	79,53	80,02
Abrasion index (–0,5 mm)	4,85	4,83	4,91	4,66	4,81
Screen analysis (–6 mm)	7,70	6,27	8,82	7,29	7,52
DMS conct., % Mn	42,1	42,01	41,99	41,80	41,98
% Fe	4,06	4,5	4,13	4,04	4,10

Decreased Productivity

After the change in feed material, there was a 10 per cent drop in the sinter-plant productivity, along with drastically increased suction on both the sintering and the cooling sections of the strand. A comparison of production parameters revealed a decrease in –1 mm material in the feed, as well as a reduced carbonate content and a decrease in tumbler strength. The decrease in –1 mm material resulted from the removal of the –0,7 mm material in the feed-preparation section of the dense-medium separation plant. This was done to prevent contamination of the ferrosilicon medium by grit. No means exists at present to upgrade this size fraction. Grit from the crushing and screening section, which used to be added to the sinter feed, is stockpiled separately at present to prevent grade dilution of the upgraded dense-medium concentrate. This fine fraction is not sufficiently regenerated in the crushing stage between the dense-medium separation and the sinter plant. As a result of the decrease in fine material, weaker and smaller nodules are formed, which in turn form a more impermeable packed sinter bed. Some particles are released from the granules during handling, and further decrease the voids between the remaining granules. As calcium is associated with the less-dense, lower-manganese carbonate minerals, and is discarded in the dense-medium separation float product, the carbonate content of the sinter-plant feed is also decreased. A decrease in calcium content reduces the basicity of the sinter and the self-fluxing properties of the ore. The lower CaO content of the ore influences the mineral phases formed during the process, resulting in a lower cold strength in the sintered product.

Optimization Philosophy and Theory

There were two possibilities to improve the reduced bed permeability:

(1) The use of a coarser sinter-feed mixture.

A coarser sinter feed had already been shown to be sub-optimum during the initial pot tests to determine the optimum sinter parameters[8]. The coke consumption increases because of the higher temperatures needed to reduce and sinter the ore sufficiently.

(2) Optimization of the quasi-granulation techniques.

The factors influencing quasi-granulation are

- the moisture content of the mixture
- the particle-size distribution of the material
- the addition of binders
- the motion of the material in the nodulizing drum.

Investigation of the addition and motion of moisture in the nodulizing drum revealed that optimum conditions existed for the present feed mixture.

The size distribution of the present feed material was found to be highly deficient in fine material. The ideal size distribution for quasi-granulation is 30 per cent –0,2 mm material and 70 per cent +0,7 mm material, with no material in the 0,2 mm to 0,7 mm size range. The tests carried out to determine the effect of fines showed that the average granule size is increased by the addition of fines but material is lost from the granules, which can lead to a lower permeability in the bed than if those fines were contained by the granules.

The effect of the addition of the following binders was tested: bentonite, molasses, Marbond (woodwork glue), a water-soluble tar suspension, and burnt lime. Molasses showed the biggest improvement for the *smallest addition*, the general effect being a more uniform particle-size distribution.

The choice of binder is governed by the following:

- It should be effective in improving the granules
- The addition of small amounts should be sufficient
- The effects of the chemical composition and the combustion residue on the quality of the sinter should be favourable
- Its costs should be as low as possible so as not to significantly increase the variable production costs.

Figures 3 and 4 illustrate the effect of fines and binder addition on the size distribution of the granules (plotted on log-log axes).

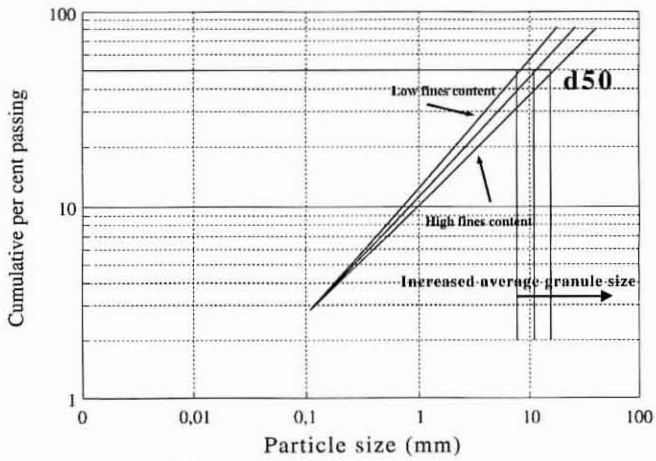

FIGURE 3. Effect of fines content on granule size

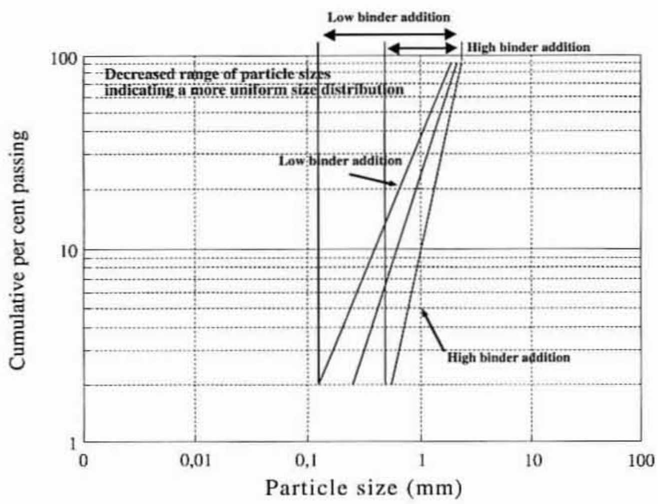

FIGURE 4. Effect of binders on granule size

It was found that a combination of an increase in fines and the addition of small amounts of binder would be the optimum solution. Tests being conducted at the time of writing indicate a reduction in suction of approximately 100 mm of H_2O at the addition of 20 to 30 per cent of –0,3 mm material and 0,15 per cent molasses.

Source of Fine Material

As mentioned earlier, an econimical means of upgrading the fine fraction to a suitable high grade has not yet been found. The addition of low-grade Mamatwan fines and slimes would result in an unwanted grade dilution of the feed material to the sinter plant. This, in turn, would require compensation in grade in the dense-medium separation plant, leading to expensive higher material losses to the discarded float fraction. Crushing of the concentrate from dense-medium separation to a greater extent produces not only more –0,2 mm material but also a proportionate amount of the unwanted +0,2 –0,7 mm fraction. Options under investigation include the upgrading of the fine material that is discarded at present with subsequent crushing, the utilization of higher-grade Wessels slimes, and the beneficiation of Mamatwan's higher-grade MnO_2 resources.

High-grade Sinter in the Production of Manganese Alloys

The advantages of sinter instead of ore as the major part of the burden in furnaces producing manganese alloys have already been discussed. When high-grade sinter was introduced to the electric-arc furnaces at the Meyerton works, even further savings were achieved over those attained by the use of low-grade sinter. Table V shows the use of a proven, accurate, computer-based smelter balance to obtain easily comparable, typical production figures for the production of 76 per cent high-carbon ferromanganese from low-grade (44 per cent manganese) sinter, 78 per cent high-carbon ferromanganese from low-grade sinter, and 78 per cent high-carbon ferromanganese from high-grade sinter (48 per cent manganese). Instead of 76 per cent high-carbon ferromanganese, 78 per cent was manufactured with savings achieved over the production of 76 per cent high-carbon ferromanganese as listed in Table VI.

TABLE V
PRODUCTION RESULTS FOR VARIOUS FURNACE BURDENS

	76% HCFeMn from 44% Mn sinter	78% HCFeMn from 44% Mn sinter	78% HCFeMn from 48% Mn sinter
Slag/metal ratio	0,768	0,989	0,644
kWh/t net	2 979	3 246	2 830
Total hot metal	1 779	1 594	1 871

TABLE VI
SAVINGS RESULTING FROM HIGH-GRADE SINTER IN THE FURNACE BURDENS AT THE MEYERTON WORKS

Energy consumption	14,69%
Production increase	17,37%
Improvement in slag/metal ratio	53,5%
Decrease in raw-material usage t/t of alloy	14,45%

Contrary to expectations, however, the consumption of electrodes increased slightly by 1 kg/MWh, i.e. 15,38 per cent. The exact cause of this increase has not yet been established, but it is thought to be a function of the higher metallic oxide content of the burden. Electrode control was slightly more unstable than with a low-grade sinter burden. The lower resistivity registered by the electrode controller causes the electrode to withdraw in order to correct for the higher current drawn. If the electrode has to be withdrawn too much, penetration of the arc is adversely affected. Better control of the coke bed just above the metal bath is required, the stability of the electrode control being directly related to the thickness of this layer. The increased thickness of the carbon causes the electrode to be lowered, resulting in proper arc penetration into the burden.

This phenomenon of electrode instability was limited to the furnaces producing ferromanganese, the silicomanganese-producing furnaces being virtually unaffected. The advantage of the self-fluxing properties of Mamatwan ore is lost when the sinter makes up more than 50 to 60 per cent of the burden, requiring the addition of more ore and fluxes to re-establish the correct slag-to-metal ratio and basicity. If the slag-to-metal ratio drops too low, the same effect is seen as when the carbon layer on the bath is too thin, resulting in poor arc penetration.

The benefits of increased refractory life could not be determined since sinter has not been used long enough in the furnace burdens.

Another factor that is not easily quantified is the furnace stability, which is greatly improved by the use of sinter. From discussions with production personnel at Samancor's Meyerton works, it is clear that the furnaces that regularly erupted rather violently when an ore burden was used, now only 'sigh' a few times per week. This fact also contributes to the higher furnace capacities by making steadier and more predictable operation possible, requiring less of a safety margin than when unexpected large eruptions have to be compensated for.

Future Prospects

As discussed, tests are in progress to find means of upgrading the fine material. A 1,5 t/h (dry solids) spiral concentrating pilot plant was commissioned recently and holds good promise.

Tests on various binders, natural and synthetic, continue. As soon as a feasible process is found to concentrate the fines, it will be implemented.

Means to economically produce a sinter containing more than 50 per cent manganese is under investigation. The addition of 'sweetener' ores is one option currently being pursued. MnO_2-type ores from the enriched zone in the Mamatwan mine and ore from the nearby Smartt mine, as well as fines of higher-grade ores from Wessels mine, are options being investigated.

The use of infrared lamps to replace the present oil-fired ignition hood is being tested on a pot scale at the time of writing. Since no furnace gas is available at the mine and heavy furnace oil has to be railed from Durban at great cost, such a breakthrough will result in large savings in fuel costs. The running costs may be found to be as low as one-third that of a conventional oil-fired hood. The energy-transfer efficiency of infrared lamps is also greater, and the downtime due to the heating and cooling schedules of a conventional furnace will be eliminated. The high capital costs involved in building a conventional ignition hood will also be greatly reduced by the elimination of refractories.

The use of infrared light to preheat the sinter bed directly after loading onto the strand will also be investigated. Large amounts of excess water could be driven off in this way prior to ignition, resulting in quicker ignition and faster burn-through rates.

At the time of writing, the manganese mines had undergone their first audit by a third party, TUV Rheinland, and succeeded in qualifying for a listing under ISO 29002, and EN 9002, which are international standards pertaining to quality assurance.

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