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"THE SILICOMANGANESE PRODUCTION PROCESS AT TRANSALLOYS"

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ABSTRACT

Transalloys have been producing silicomanganese for more than 20 years. The main source of manganese input is the carbonaceous ore from the Kalahari manganese field.

Relatively high slag to alloy ratios are a feature of the process at Transalloys. In order to achieve acceptable manganese recovery levels, the composition of the slag and more specifically the effect of composition on MnO content is most important. Initially serpentine was used as a fluxing agent, to be replaced by magnesite and sometimes dolomite at a later stage. Plant operating data were collected over long periods of time, covering slag basicities ranging from approximately 0.7 to unity and slag to alloy ratios from about 1.5 to 2.2.

It was observed that manganese losses to slag decreased at higher basicity levels, but the MgO content of the slag needed to be maintained above approximately 17% in order to achieve good recoveries.

1. INTRODUCTION

Transalloys was the first industrial venture of Anglo American Corporation of South Africa and is now a fully owned division of Highveld Steel and Vanadium Corporation Limited.

Transalloys commenced operations in 1964 as a producer of low carbon ferrochrome. At it's inception, the works comprised two 15MVA submerged arc furnaces and two 4MVA open-arc melting furnaces. Conditions in the ferrochrome market were not too favourable and in the late sixties it was decided to switch to the production of manganese alloys.

The Company quickly established itself as a reliable producer of silicomanganese and medium carbon ferromanganese, the latter by means of silicothermic reduction of a manganese ore/lime melt.

The total production capacity is approximately 175 000 tons silicomanganese and 50 000 tons medium carbon ferromanganese per annum.

The Transalloys works are situated adjacent to the Highveld Steelworks in Witbank (Eastern Transvaal Province) and are listed under ISO 9002.

The company does not possess an in house source of ore. Manganese ore is purchased mainly from Samancor and Associated Manganese and is railed to the works from Hotazel in the Northern Cape province. Reductants and fluxes are available locally in the Eastern Transvaal.

2. BRIEF DESCRIPTION OF PLANT

Following a successful conversion to manganese alloys production, plant capacity was expanded a number of times.

In the seventies, the original two submerged arc furnaces were uprated from 15 to 21MVA and the melting furnaces from 4 to 7MVA. In 1976, a new 48MVA furnace was commissioned. This was followed in 1981 by a 22MVA furnace and finally by another 48MVA submerged arc furnace in 1990. Because of poor market conditions the latter furnace was only fully commissioned in 1992. The melting furnaces and the latest 48MVA furnace were supplied by Mannesmann Demag, all other furnaces are of Elkem design.

The submerged arc furnaces are aligned alongside a spacious tapping hall, served by four overhead cranes. Silicomanganese is cast into small ingots on a double strand casting machine. A single strand machine is used to cast medium carbon ferromanganese.

The two alloys are processed through dedicated crushing and screening plants and the finished products stored in totally separate areas to prevent chance cross-contamination.

Molten discard slag is dumped, using Komatsu slag pot carriers.

3. OPERATING PRACTICE

3.1 General

The silicomanganese operation is based on the almost exclusive use of Mamatwan type ores. Because of the high lime content of this ore, relatively large quantities of flux are required to produce an acceptable slag. Some typical raw material analyses are given in Table I.

TABLE I - TYPICAL RAW MATERIAL ANALYSES (% BY MASS)

1. **Manganese ore**

Mn	38.5
Fe	4.4
SiO_2	5.2
CaO	14.5
MgO	3.8

2. **Quartzite**

SiO_2	97.0
Al_2O_3	1.5
Fe_2O_3	0.7

3. **Reductants**

	Coal	**Coke**
Volatiles	23.0	1.0
Ash	20.0	18.0
F.C.	57.0	81.0

Slag melting temperature and viscosity were initially controlled by the addition of serpentine and quartzite as fluxes.

On all furnaces slag and metal are tapped through the same taphole. A launder is used to convey the material to a refractory lined metal ladle. The launders are of steel construction, with a refractory lining. On top of the refractories, a 200mm layer of baked ramming paste serves as a working lining. The launder tip is of similar construction but in addition a block of baked paste is provided to serve as a "lip". The launder tip is easily removable and can be changed quickly. Under normal conditions, tips are replaced after approximately 150 taps.

The metal ladles are lined with superduty fire brick, but discard slag is used as a working lining. The furnaces are tapped at two hourly intervals.

After each tap, the ladle is inspected and build-up removed, if necessary, by means of a rock drill. The slag lining is replaced by simply filling the ladle with molten slag, allowing it to stand for some time, and pouring off the excess. The refractory lining usually has to be replaced only after about 700 cycles or more. Some experience was built up using a back lining of baked ramming paste. Because of the relative ease of cleaning slag accretions from this lining, less mechanical damage is experienced and longer cycle lives are achieved.

The supernatant slag in the metal ladle overflows into one or two cast steel slag pots. Once the taphole has been closed, the slag remaining in the metal ladle is decanted into a slag pot. However, a small quantity of slag is retained in the ladle. It is decanted separately just prior to the metal casting operation, in a separate area.

This material, named metallic slag, contains about 10 per cent by mass of alloy.
It is cooled, crushed and screened and the + 12mm fraction recycled to the submerged arc furnaces.

Fines are agglomerated in a brick-making type of operation and also recycled.

All dust collected in the bag filters is pelletised. It is not necessary to add a binder and the pellets cure to an adequate hardness within a few days. They are recycled to the submerged arc furnaces on a continuous basis.

The resulting slag to alloy ratio in our process is approximately 2 to 1, but certain deviations will be discussed in the following section. The slag to alloy ratio is controlled by controlling the ratio of ore to recycle slag in the furnace feed.

As far as composition of the alloy is concerned, some special requirements have to be mentioned.

Because a significant portion of the silicomanganese produced has to be suitable for making medium carbon ferromanganese, the manganese content needs to be fairly high with a low iron content. In order to ensure continuous availability of molten reductant, at least one 48MVA and one 22MVA furnace must produce this special quality alloy. Obviously only a certain portion will be used internally, the remainder being combined with other production for external sales. Some relevant analyses are shown in Table II.

TABLE II - SILICOMANGANESE ANALYSES (% by mass)

Element	Commercial specification	Molten reductant	Final products typical
Mn	65 min	68.5 min	67.0 - 68.0
Si	15 - 18.5	16.5 min	16.5 - 17.5
Fe	balance	10.5 max	12.5 - 13.5
C	2 max	1.6 max	1.60 - 1.80

All silicomanganese alloy (molten reductant excepted) is cast on a double strand casting machine. The ingots produced by the machine do break up but the generation of fines has been found to be far less than when the alloy is cast into large slabs and then broken up.

About 7% of the alloy as cast is screened out as - 3mm fines, this material being utilised as a solid reductant in the medium carbon ferromanganese operation.
Approximately 15% reports as 12mm by 3mm fines and is consumed by the steelworks or can be used as a solid reductant.

3.2 Slag Composition and it's effect on performance

In view of the prevailing high slag to alloy ratios, relatively small changes in the MnO content of the slag affect the manganese recovery significantly.
It was recognised at an early stage that the slag should contain at least 7% MgO to improve slag fluidity and manganese recovery.

Serpentine was used initially and with reasonable success. However, the combined silica in this mineral did not take part in the reduction reaction and just diluted the slag. Quartzite was still required to produce silicon and to flux the excess lime.

Several alternatives to obtain a higher MgO content in the slag without any undesirable side effect were considered.

Eventually it was decided to evaluate the replacement of serpentine by naturally occurring magnesite. For economic reasons a fraction containing 2 - 6 per cent free silica was selected.

Typical analyses of the two materials are shown in Table III and of slags produced in Table IV.

TABLE III - ANALYSES OF SERPENTINE AND MAGNESITE

	Serpentine	Magnesite
% MgO	35 - 37	44 - 46
% CaO	4 - 5	1 - 2
% SiO_2	37 - 39	2 - 6

TABLE IV - SLAG ANALYSES (% BY MASS)

	Fluking Agent	
	Serpentine	Magnesite
MnO	11.1	8.5
SiO_2	45.4	46.0
CaO	24.2	23.1
MgO	14.4	17.8
Al_2O_3	4.0	3.8

It was found that improved recoveries and better power consumption could be achieved and further work was done to optimise the quantity of magnesite used in the process. In this respect, there are several practical implications that affect the limit of the quantity of magnesite that can be added.

This limit is not only defined by the liquidus temperature and viscosity of the slag but also by economic factors such as reductant consumed by the carbonate present in the magnesite and the overall energy consumption.

In our work, the MgO content of the slag was limited to approximately 20%, as higher contents made the operation unstable and had a marked adverse effect on energy requirements.

Figures 1 and 2 show the relationship between MnO and MgO content of the slag, where Figure 1 covers a period when only serpentine was used. Figure 2 relates to a period when magnesite was used predominantly, but minor quantities of dolomite were added occasionally, replacing approximately 15 - 20% of the magnesite input. The silica content of the slag averaged approximately 45% SiO_2, with a range of 44.5 - 45.6%.

In both cases, the slag to alloy ratio varied between 1.94 and 2.10. It will be noted that a significant reduction of the MnO content of the slag was achieved by increasing the proportion of MgO in the slag.

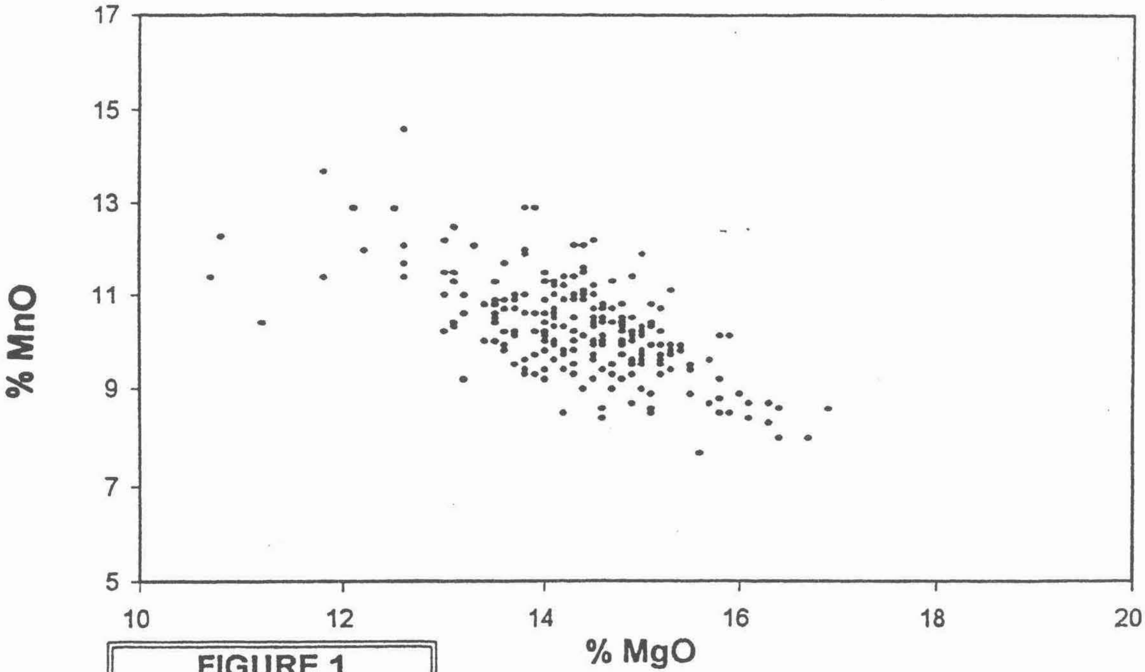

FIGURE 1
MnO vs MgO IN SLAG

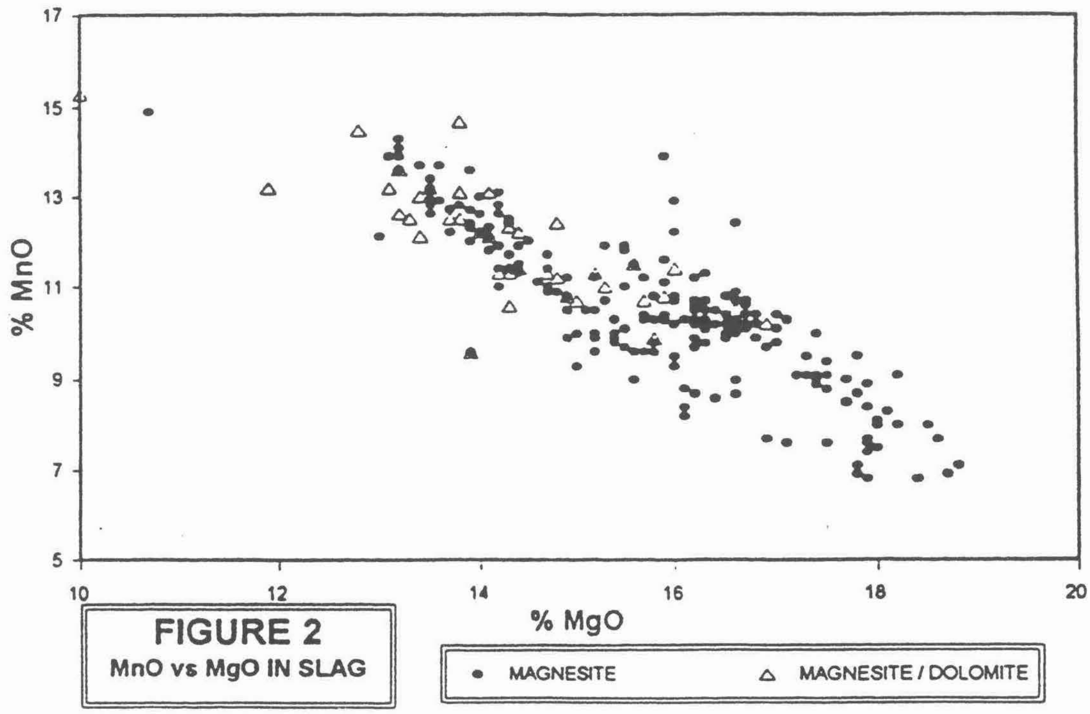

FIGURE 2
MnO vs MgO IN SLAG

Turning to the base/acid ratio, which is here defined as (%CaO + MgO)/ %SiO_2, the MnO decreased with increasing base/acid ratio as could be expected. It was observed, however, that replacing a proportion of the MgO by CaO to obtain a similar base/acid ratio almost invariably yielded higher MnO contents in the slag (See Figure 3).

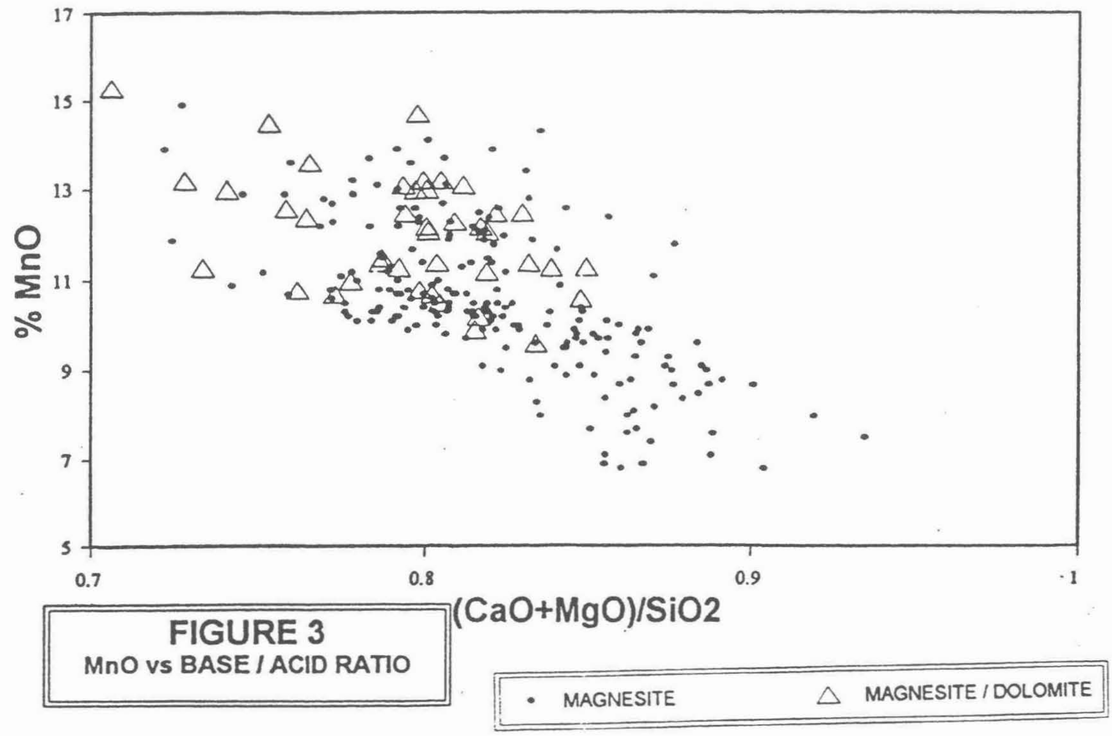

FIGURE 3
MnO vs BASE / ACID RATIO

This observation supports the suggestion that MgO enhances the activity of MnO in the slag under the prevailing conditions.

3.3 Other operational aspects

An aspect of possible interest is that the two 48MVA furnaces at Transalloys were designed by different suppliers, Elkem and Mannesmann-Demag (MD).

The electrode diameters and pitch circle diameters are identical, as are the diameters of the hearths. However, the depths of the hearths differ, the Elkem furnace being 4.30m deep and the MD furnace appreciably shallower at 3.40m.

The Elkem furnace has been in operation since 1957, whereas the MD furnace was commissioned and in full operation from late 1992.

Traditionally the Elkem furnace was operated at relatively high slag to alloy ratios of not less than 2 to 1. It was attempted a number of times to operate the furnace at a lower ratio of 1,5 to 1 at the most. These attempts were never successful in that, although the initial performance following the change in feed might be promising, no longer term benefits could be achieved. Operating problems, mainly related to electrode management and tapping of the furnace, would develop and the manganese recovery and energy consumption deteriorate to unacceptable levels.

The MD furnace was operated on the same "standard" burden as the Elkem unit initially. However, the furnace proved to be appreciably less energy efficient, although the manganese recovery was similar to that obtained in the Elkem. It was decided to reduce the slag to alloy ratio by minimising the proportion of recycle slag and also by introducing some siliceous manganese ore that had become available.

Eventually the MD furnace was operated on a slag to alloy ratio of approximately 1.5 to 1. Recovery and energy consumption improved to levels equal or better than the Elkem unit but attempts to introduce the new burden to this furnace again met with unsatisfactory results. A qualitative indication of the performance of the two furnaces at different slag to alloy ratios is given in Figure 4.

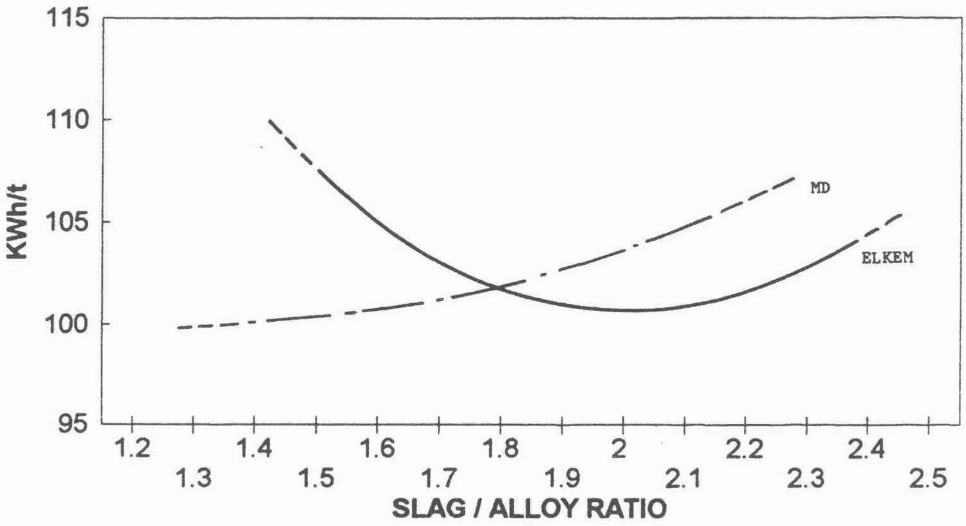

FIGURE 4
ENERGY CONSUMPTION VS SLAG/ALLOY RATIO

Although it would be of interest to pursue the matter further and, more specifically, incorporate variables such as electrode management, the amount of time available to experiment with full scale production units is of necessity very limited.

One of the 22MVA was constructed with a rather deep hearth, of approximately 3.5m. The other two furnaces which were uprated from 15MVA electrically, are comparatively shallow. Again, it was possible to operate the latter two furnaces at slag to alloy ratios ranging between 1.5:1 and 1.7:1 without any problem. However, similar slag to alloy ratios were not easily maintainable in the deeper furnace.

5. ACKNOWLEDGEMENTS

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