The Technical Development of Amcor Limited, with Particular Reference to the Production of Ferro-alloys

by J.J. COETZEE* (presented by Mr Coetzee)

SYNOPSIS

The exploitation of the base-mineral wealth of South Africa was pioneered by the formation of African Metals Corporation Limited (Amcor) in 1937, under its founder and first Chairman, Dr H.J. van der Bijl.

Starting with one small blast furnace in Newcastle, Natal, it commissioned the first furnace of a new factory at Vereeniging, Transvaal, in 1942, thus introducing to South Africa the use of electric reduction furnaces for the production of ferro-alloys.

In 1950, a third plant was erected at what is now known as the Kookfontein Works, near Meyerton, Transvaal, 15 km north of Vereeniging. By the middle of that decade, all the furnaces at the old Vereeniging site had been moved to Kookfontein, and three new units had been added. With the addition of two more furnaces in the early sixties, the Kookfontein plant reached an installed capacity of 60 MVA.

The next move was for Amcor to acquire, in 1959, the Witbank plant of Ferrometals Limited. Very soon it became necessary to add a 15 MVA furnace to the two 7,5 MVA units already in this plant.

It soon became obvious that South Africa was destined to become the major ferro-alloy producer in the Western World, particularly of chromium and manganese alloys. Early in 1970, Amcor therefore decided on a major expansion programme.

Four large furnaces were planned, each of 48 MVA capacity, in line with modern trends. Two were for Ferrometals Limited (one each for ferrosilicon and ferrochromium alloys), while two high-carbon ferromanganese furnaces were to be installed in the Kookfontein plant of Metalloys Limited, both subsidiary companies of Amcor. These were all commissioned during the period 1972 to 1974.

In the meantime, Metalloys Limited also installed furnaces and equipment to increase its output of 15 per cent ferrosilicon, which is used widely in heavy-medium-separation plants.

All these facilities, at present giving the Amcor companies a gross installed capacity of some 300 MVA and delivering a wide spectrum of alloys, make it a significant producer. It certainly is the oldest and the major producer of ferro-alloys in Southern Africa.

INTRODUCTION

South Africa was fortunate to have several outstanding men in the technical field during the first half of this century. None of these was of a higher stature than the late Dr H.J. van der Bijl, who pioneered not only the generation of electrical energy from the enormous reserves of low-grade coal in this country, but also the establishment of an integrated steelworks and, last but not least, the exploitation of the mineral wealth in base metals by the formation of African Metals Corporation Limited.

When this company was incorporated on 23rd July, 1937, one of the objects set out in its Memorandum of Association was '. . . to develop and turn to account base metals and minerals of every description found in South Africa . . . to investigate the economic feasibility of establishing iron and steelworks and other works for the production of ferro-alloys . . .'

This company is today known as Amcor Limited and its ferro-alloy interests are handled by two subsidiary companies, Metalloys Limited and Ferrometals Limited.

From these humble beginnings, when foundry pig iron and high-carbon ferromanganese were first produced in 1938 in a reconditioned 10ft-hearth blast furnace purchased from the Union Steel Corporation and situated at Newcastle, Natal, its operations have grown to two plants with a gross installed electric smelting capacity of some 300 MVA in 18 furnaces for the production of ferro-alloys alone.

The story of the development of this industry is a saga of pioneering effort.

VEREENIGING FERRO-ALLOY PLANT

When it was decided, in 1939, to erect an electric furnace plant for the production of ferro-alloys at Vereeniging, Transvaal, the Second World War was already looming large on the horizon.

Lack of capital, the effect of the War, which had broken out in the meantime, and the secretiveness of the ferro-alloy industry at that time, made it extremely difficult to obtain furnace design and operating 'know-how', and the specialized equipment required for the furnaces.

Amcor owes much to Rand Carbide Limited for making available whatever knowledge they had in this respect, based on their experience of carbide smelters. In fact, the first two reduction furnaces and carbon-paste plant, erected on the Vereeniging site, were almost entirely based on their designs and practices.

These furnaces had rectangular crucibles, 20 ft long by 6 ft wide, inside the refractory linings and were equipped with three 33-inch diameter Söderberg electrodes placed in line. Each was backed up by three 1000 kVA transformers in a delta-star configuration. Thus, the star point was made at the back of the furnace, and from there on no interleaving of bus-bars between phases was possible.

The Söderberg-electrode paste was made from a mixture of 75 per cent, by mass, of milled Natal metallurgical coke, 22½ per cent of pitch, and 2½ per cent of creosote oil.

It is no surprise that the Works Manager reported, at the end of March, that 220 ft of electrodes had been rammed on the first furnace in the six weeks since the 15th February, 1942, when the first furnace had been switched in. Owing to numerous electrode breaks, the output was only 100 tonnes of high-carbon ferromanganese.

The second unit was commissioned on 23rd April, 1942, for ferrosilicon. By then, the paste quality had already been improved, so that, by May, the number of

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electrode breaks was reduced drastically and production showed a sharp upward trend.

By the end of that year, the first of two refining furnaces for the production of medium- and low-carbon alloys was commissioned, followed in January 1943 by the second unit. These were 3-tonne, tilting furnaces, equipped with 8-inch diameter graphite electrodes and 1,2 MVA three-phase transformers.

This Vereeniging ferro-alloy works of Amcor had many firsts to its credit up to 29th March, 1953, when it was finally closed down for transfer of the equipment to a new site, the Kookfontein Works.

Apart from being the first really full-scale ferro-alloy plant in South Africa, producing primarily high-carbon ferromanganese and ferrochromium alloys, it also made ferrosilicon, silicoferrochromium, and the low- and medium-carbon alloys of chromium and manganese. But this was not all.

To meet the demands of the War, the Works was called upon to produce ferrotungsten, ferrotitanium, and even lead for the electric-cable industry. Further, there was an urgent need for certain stainless-steel products, particularly for the martensitic 13 per cent Cr steel used in rock-drill liners for the mining industry. Amcor produced over 3000 tonnes of this steel during the period from July 1943 to the end of 1948. The steel was processed into tubes by the Union Steel Corporation and Stewarts & Lloyds. As a sideline, the works also made 18 tonnes of low-carbon 18/8 austenitic chromium—nickel stainless steel in 1944, which was rolled into sheets by Iscor and subsequently fabricated into utensils required for the war in Burma.

More interesting, perhaps, is that all this stainless steel was produced direct from chromium ore, ferrosilicon being used as reducing agent. Low-carbon alloy was used only to finish the melts. This process proved more economical than what was then the orthodox method.

The available furnace capacities in South Africa were at a premium, and Amcor was asked to make mild steel in the refining furnaces whenever they were available, to assist, firstly, the Union Steel Corporation Limited and, later, the Dunswart Iron & Steel Company to increase their outputs. In fact, during the ten-year period from 1943, over 80 000 tonnes of mild steel was made.

PROBLEMS

At a very early stage of the operations, it became clear that the electrothermal production of ferro-alloys required solutions to three main problem areas to make it economically viable. The first of these, the unsatisfactory quality of the Söderberg-electrode paste, has already been mentioned.

The second was to find a carbon reducing agent or agents that would make it possible to obtain reasonable electrode penetrations into the furnace burdens for the different alloys.

And, lastly, there was the problem of rapid deterioration of the furnace equipment, particularly electrode contact shoes, flexible current conductors, and refractories. These difficulties were undoubtedly aggravated by the frequent electrode breaks and hot bed tops due to insufficient electrode penetration.

Söderberg Paste

In June 1947, a small quantity of paste imported from Norway was tried out on the Vereeniging plant furnaces with good results. Lengthy negotiations then took place, with the company that had supplied the paste, about a plant in South Africa for an improved paste. Tests on South African anthracites and binders, and the fact that they were then developing an improved type of anthracite calciner, delayed the matter, and it was almost ten years before the new rotary calciner and paste plant were commissioned. By that time, all the furnaces had been resited at the new Kookfontein Works, and the paste plant was installed on that site.

In the meantime, the new furnaces installed at the Kookfontein Works with larger electrodes could not operate on the paste made at the Vereeniging Works. Arrangements were therefore made to obtain a better-quality paste for these units from the Rand Carbide Company. History has, however, now repeated itself, and, because of the demands for the very-best-quality paste for the modern large furnaces recently installed, it became necessary to put in even better facilities for paste manufacture, based on the most advanced technological developments to date.

Again, after a thorough investigation, Amcor turned to the Norwegian company to supply the 'know-how' and design for the new paste plant. This plant was erected on the Ferrometals Limited site at Witbank and came into use in the middle of 1973.

The seriousness of an electrode break in large, covered furnaces cannot be over-emphasized. It is virtually impossible to remove the broken-off stump from the hearth, and the pieces of electrode in the furnace may affect the operation for many weeks, with disastrous results on the economy of the unit.

Electrode Penetration

It was found extremely difficult, at a very early date, to get satisfactory electrode penetration with the available reducing agents in South Africa. These were metallurgical coke or coke breeze, coal, and anthracite. Except for a small quantity of gas coke from the Johannesburg gasworks, no low-temperature coke was available.

It was only when the Rand Carbide Company installed their first coal-charring plant, that a better reducing agent, particularly for use in ferrosilicon production, came onto the market.

Not until the technique to use coal of specific properties and size range was successfully introduced into high-carbon ferromanganese furnaces in the sixties, did it become possible to achieve adequate burden resistance for good electrode penetration for this alloy. Without this development, it would perhaps not have been possible to achieve satisfactory operation on the new 48 MVA furnaces for ferromanganese.

The search for better reducing agents at reasonable costs is continuing. I am convinced that the availability of a reasonably priced, low-temperature coal-char could materially alleviate this problem. Such a reducing agent would be required in the size range of 20 to 6 mm for use in electric reduction furnaces. If made on a large scale, and if the fraction larger than 20 mm could be sold as a smokeless fuel for household use, it might be possible to achieve a production cost that would make it attractive for ferro-alloy producers.

Furnace Maintenance

When Amcor started, very little was known in this country about suitable refractories for furnace linings for the different alloys to be made. Coupled with the necessity for frequent changes of product to be made in the few available furnaces, it led to the dubious record that both of the first two reduction furnaces had to be rebuilt before the end of the first year of operations.

Over the years, this difficulty has been alleviated, mainly by the use of carbon-paste or carbon-brick linings, but it cannot be said to have been solved. As more furnaces became available, the frequency of product changes was reduced, and this also improved conditions.

However, we still have to live with occasional furnace breakouts, and, in the latest furnace designs, a special trough is built round the furnace bottoms to catch the metal and slag discharged during a breakout and conduct it away from the furnace.

Damage to the electrode gear above the furnace, particularly contact shoes, pressure rings, and flexible electrical conductors, has been much reduced by better design. This is effected in the more modern furnaces by the roof cover and, in open furnaces, by a heat-shield constructed round the whole electrode assembly up to and through the fume-hood top.

KOOKFONTEIN WORKS

After the War, the need for additional production capacity made itself felt. The old site was too small for significant expansion, and the first pressures to remove the major sources of air pollution – the open ferromanganese furnaces – from a largely residential area forced a decision to move the whole plant to a larger site some 13 km north, near Meyerton, now known as the Kookfontein Works.

To facilitate this move without interrupting production, two 13,2 MVA furnaces were bought second-hand in England after the War. These units had been installed at Cardiff to make ferrosilicon for British War Supplies. The transformers for these units had originally been built for a ferronickel smelter at Petsamo in Finland but were never shipped. They were not ideal for ferro-alloy production, particularly ferromanganese, because they had a constant kVA rating only above 130 V, which is high.

However, these units, together with two overhead cranes, were the first furnaces to be installed at Kookfontein. Completely new shells and bus-bars were installed to adapt them to the manufacture of manganese and chromium alloys.

The first unit, now known as No. 3, was commissioned on 11th April, 1951, to be followed by the second one, No. 2, on 29th November, 1951.

The Kookfontein site is some 1150 acres in extent and was at that time reasonably distant from built-up areas, which made it possible to install open furnaces. Alas! this did not last long. Township developers have a habit of surrounding factories with new residential areas, and then people start to complain of the nuisance these plants constitute.

These were the first furnaces to be installed by Amcor with the electrodes spaced at the apexes of an equilateral triangle and the bus-bars interleaved in a 'Knapsack' connection. They had 41,25-inch electrode diameters, and the electrodes could be moved to give ratios of pitch-circle diameter to electrode diameter of from 3,1 to 3,9 for the unit manufacturing ferromanganese, and from 2,8 to 3,6 for the one manufacturing high-carbon ferrochromium.

With electrode current densities of from 34 to 39 A/in^2 at normal operating voltages and with thermal loads on the hearth floor area of about 28 kW/ft^2 in an inverted-cone tapered shell and lining, these furnaces were an improvement over the old units.

For the record, power consumption (net furnace power per unit mass of salable product) was around 3000 kWh per short ton for ferromanganese – not significantly better than previously achieved in the Vereeniging units. This was a disappointment in view of our optimistic forecasts when these furnaces were designed.

The demand for alloys increased unabated as the export market for ferro-alloys, first entered in 1950, was being expanded. Despite the fact that the Newcastle blast furnace was still making ferromanganese and the two new furnaces at Kookfontein operated to capacity, the old furnaces at Vereeniging could not be taken out for transfer to Kookfontein. Before this could be done, a third new furnace, now called No. 1, had to be put on-line at Kookfontein. This 7,5 MVA unit started operations on 21st September, 1954, and was the first furnace in Amcor's history equipped with remote-controlled electrode slipping devices. It had 36-inch diameter electrodes, operated at around 40 A/in^2, and had a ratio of pitch-circle diameter to electrode diameter of from 1,95 to 2,5. The hearth thermal load was 30 kW/ft^2. This unit was designed, basically, for the production of 70 to 80 per cent ferrosilicon.

In anticipation of the output from this unit and while Newcastle was still helping out on ferromanganese, the furnaces at the Vereeniging Works were taken out of commission during February and March 1954 and transferred to Kookfontein.

The two tank furnaces were redesigned completely, only the transformers and electrical gear being retained. They now became circular furnaces with the electrodes placed in a triangle. The electrode diameters were reduced to 31 inches, and the ratio of pitch-circle diameter to electrode diameter was fixed at 2,51 to 1 for the production of high-carbon ferrochromium. The hearths had a thermal load of 28 kW/ft^2. These furnaces are now Nos. 4 and 5 units.

With the resiting of these furnaces and the two 1,2 MVA Birlec refiners, as also the experimental furnace of the same capacity, during the period October 1954 to July 1955, the Kookfontein Works reached an installed capacity of 45,5 MVA.

The result was that, during the first full financial year in which all these furnaces were in action (ending on 31st March, 1957), the Kookfontein Works produced 55 639 short tons of all types of alloys. The value of Amcor's exports of alloys for that year exceeded £2 million for the first time.

Still the demand for more ferro-alloys persisted. Two more furnaces were added to the line: a 7,5 MVA unit on 1st October, 1957, now No. 7, and a 6 MVA unit in 1962, now No. 6. Furthermore, the No. 1 furnace was uprated to 10 MVA, and the electrode diameters were increased to 43 inches. During the same period – from 1960 to 1963 – Nos. 2 and 3 furnaces were rebuilt: their electrode diameters were increased to 50 inches, and they were all equipped with roofs and gas-cleaning plants.

When No. 7 furnace was designed to produce 70 to 80 per cent ferrosilicon, it was decided to make this a rotating unit because the company needed experience on such a furnace, for which all sorts of advantages were claimed. After almost two years of trials, this was converted to a stationary unit, because it proved impossible to demonstrate these advantages. This was the first and last rotating furnace ever installed in the Amcor group.

FERROMETALS LIMITED

To meet the insatiable demand for alloys, Amcor acquired the plant of Ferrometals Limited at Witbank on 1st December, 1959. This plant had two 7,5 MVA furnaces already producing silicon alloys, which immediately reduced the pressure on the Kookfontein Works. Nevertheless, plans had to be put in hand soon after for a third 15 MVA furnace. This came on-line in January 1963.

For the first time, a furnace designed and erected by an outside contractor (Demag) was installed. The unit had 45-inch diameter electrodes, placed in a triangular arrangement and giving a ratio of pitch-circle diameter to electrode diameter of between 2,31 and 2,55. The current density was 42,13 A/in², and the hearth had a thermal load of some 36,65 kW/ft².

The furnace has operated for ten years on 70 to 80 per cent ferrosilicon, but has now been rebuilt to make charge chromium.

A PERIOD OF CONSOLIDATION

Now, at last, a period of consolidation arrived, and time could be devoted to the improvement of production, despite a steady decline in the properties of raw materials.

Outputs of the furnaces in Newcastle, Kookfontein, and Witbank increased from 184 000 short tons in 1965 to 203 000 short tons in the financial year 1968-1969.

Illustrative of these developments was the replacement of coke by coal in the high-carbon ferromanganese burdens during the period 1964 to 1969. Success did not come easily and was achieved only after the problems that caused explosions, sometimes serious ones, in the furnaces had been solved.

The whole process to produce silico-ferromanganese also had to be revised because the siliceous manganese ores of a reasonably constant grade that had been used became unobtainable. The duplex process, using slag from the high-carbon manganese furnaces, was introduced successfully but only after many months of experimentation.

These developments are a tribute to the work of the company's metallurgists.

15 PER CENT FERROSILICON

Amcor pioneered the production of 15 per cent ferrosilicon for use as a powder in heavy-medium ore-beneficiation plants in South Africa.

The first production of this alloy took place in the old 1,2 MVA pilot furnace at the Vereeniging Works in May 1949. To mill the metal to the required powder, an old Krupp batch mill was used. It was soon realized that a batch-milling process was too expensive and not capable of giving the required range of particle sizes. Once again, Amcor had to develop the design of a satisfactory air-swept ball mill and classifier—cyclone system for this product because no assistance could be obtained at the time from vendors of mills.

The first deliveries of powders for test purposes, in both the 65D and 100D sizes, were made during May 1949 to the Premier Mine, among others, for use in their heavy-medium-separation plant for the recovery of diamonds.

From this primitive set-up, the production facilities have been enlarged and added to over the years, culminating in the commissioning, in May 1972, of a new 7,5 MVA furnace specifically designed for the production of this alloy.

It has ELKEM electrode equipment and uses 35-inch diameter electrodes in a triangular configuration, giving a ratio of pitch-circle diameter to electrode diameter of 2,87, an electrode current density of 41,6 A/in², and a hearth load of 41,9 kW/ft².

Technological development in the heavy-medium-separation process today also requires a more sophisticated medium than the milled powders. Such a product is the so-called atomized ferrosilicon developed by Knapsack A.G. in Germany.

An arrangement was therefore made to make available to Metalloys Limited the design and production 'know-how' of Knapsack A.G. for a plant to produce atomized ferrosilicon. This came into operation in July 1970.

Metalloys Limited is thus today able to supply the local mineral industry with a wide range of powders, both the milled and the atomized product, to cater for its various needs.

THE MASSIVE FURNACES OF THE SEVENTIES

With this history of continual expansion in the ferro-alloy industry behind it, the Amcor companies were well-poised to take advantage of the tendency, which became apparent in the late sixties, for a rapid expansion of production facilities in South Africa. Indeed, the extremely large reserves of chromium and manganese ores in this country, combined with the fact that electric power is available in quantity at a reasonable price, make it unavoidable that it will become the major ferro-alloy producer in the Western World.

Amcor therefore decided early in 1970 on a major expansion programme. Groups of technical officials visited a number of ferro-alloy plants in Japan and Europe, where most of the technical developments in this industry had taken place during the past decade. Discussions in depth with all the major suppliers of furnace installations were held to determine to what extent their equipment would suit South African conditions or could be modified

Table 1

Design features of 48 MVA ELKEM furnaces

Furnace	Product	Electrode diameter mm	Ratio of pitch-circle to electrode diameters	Electrode current density A/in²	Hearth load kW/ft²
Ferrometals A	70 to 80% FeSi	1550	2,5 2,82	38	54
Ferrometals No. 4	Charge chromium	1700	2,51	31	38
Metalloys A	High-carbon FeMn	1900	2,86	25	34
Metalloys B	High-carbon FeMn	1900	2,86	25	34

for this purpose.

Eventually, four 48 MVA furnaces were ordered, two of which were to be erected at the Ferrometals Works and two at the Metalloys plant at Kookfontein.

All the furnaces, except the one used for ferrosilicon production, which is open, have roofs and venturi-type, wet gas-cleaning plants. Some details of their design are given in Table 1.

The Ferrometals A furnace was commissioned in March 1972, to be followed by No. 4 in February 1973. The two Metalloys furnaces started operations in the latter half of 1973 and early in 1974.

These furnaces are very much more sophisticated than the furnaces to which the Amcor staff are accustomed, and require more-intensively trained operators and maintenance personnel. It is also essential to feed them with better-prepared raw materials for the best results.

Furthermore, much more attention has to be given to the efficient handling and disposal of the large quantities of metal and slag that they spew out. The best and most economical methods for solving these particular problems have not yet been found.

With the addition of these large furnaces to its already impressive line of production facilities, the Amcor group of companies are now able to produce a wide range of ferro-alloys in the ferrosilicon, ferrochromium, and ferromanganese fields. It can be said, without reservation, that Amcor is today not only the oldest ferro-alloy producer in South Africa but also the major operator.

In presenting his paper, **Mr Coetzee** pointed out that he had been approached by the INFACON Organizing Committee to present a less sophisticated and more digestible paper on Amcor's developments in the production of ferro-alloys. Mr Coetzee stressed that his paper had been compiled with the above requirements in mind. He indicated that the human resources of a company are its most valuable assets and, in this respect, he was encouraged to see how many companies had allowed their officials to present papers at INFACON 74, giving details of production techniques, furnace design, and process control. Mr Coetzee said that this had not been the case some years before, when the ferro-alloy industry was closely guarded and technical information was not readily exchanged. He said that the spectacular developments in the ferro-alloy industry in Japan during the past decade may have changed the secrecy that had previously been encountered.

The modern trend towards bigger furnaces and the associated larger capacity, which Amcor had accepted on a large scale, presented new problems. These large furnaces are relatively sluggish in following changes in operating conditions, thus demanding a far greater degree of expert control than is necessary with smaller furnaces. He noticed, with interest, a paper that described the successful computer control of such a large furnace. He felt, however, that a warning should be sounded – that the installation of computer control on a furnace did not mean that one could now neglect the prerequisites of good furnace operation, namely the chemical and physical characteristics of the raw materials in a furnace burden. He stressed that the control of these chemical and physical properties was even more necessary in large computer-controlled furnaces than in small furnaces.

Referring to his paper, Mr Coetzee noted that, in addition to those quoted in the paper, a further 48 MVA furnace was then under construction at the Ferrometals plant. This was No. 5 furnace, similar to No. 4 except for a rearrangement of the bus-tubes to decrease the reactance. A novel feature in this installation was the provision of equipment in which the major portion of the product (charge chromium) would be water-cooled granules, and not pigs as in the pig casting of the No. 4 furnace product.

Also mentioned were two further large furnaces in the planning stage, one for 70 to 80 per cent ferrosilicon and one for charge chromium. The sizes of these units were still to be decided, but they were unlikely to be smaller than the present 48 MVA furnaces.

With all these furnaces in use, or envisaged in the near future, it had become necessary to extend the Söderberg paste plant at Ferrometals even before operations had started. Mr Coetzee mentioned that high-carbon ferromanganese was still being made, under contract to Amcor, in a blast furnace at Iscor's works at Newcastle. This was in addition to the ferromanganese produced in the electric furnaces at the Metalloys plant. However, it was envisaged that, in future, increasing ferromanganese production from Mamatwan ore might take place in blast furnaces, which could be situated inland or at the coast. As there was also an increased demand for ferrosilicon-manganese, and as this product required an enriched manganese slag in an integrated process, it was not unlikely that further large-capacity furnaces might be installed at Metalloys.

Mr Coetzee then mentioned the prerequisite for further increases in production, namely the use of fine ore since the South African ore had only 10 to 20 per cent of hard, lumpy material. He mentioned three methods of agglomeration under study today – sintering, pelletization, and pelletization with prereduction of a portion of the chromium and iron oxides. For full advantage to be gained from the last-named process, hot pellets should be charged to the reduction furnace. This, however, made operations more difficult because proportioning of the furnace mix became almost impossible.

The order in which the above agglomeration processes were mentioned was also the order of capital cost of these plants and their production costs.

Mr Coetzee also found that the production cost of charge chromium in South Africa from lumpy ore or lumpy ore with 50 per cent sinter or cold pellets, and also if only prereduced pellets were used, would result in substantially the same product cost if depreciation charges and cost of capital were considered. His choice would be sintering because it was a well-proved technique and also had the advantage of not requiring milling, provided that the particles were smaller than 6 mm. He mentioned that all routes of using fines were under study by Amcor.

Commenting on the considerable shortage of suitable reducing agents in South Africa, Mr Coetzee said that Amcor had proved that high-carbon ferromanganese furnaces could be operated satisfactorily on some South African coals. The charcoal produced by Rand Carbide Limited was a good reducing agent for ferrosilicon but was unsuitable for charge-chromium production. Indications were that the Rand Carbide coal char could be tolerated with a wider size spectrum. This coal char could be obtained from a non-coking coal that was more abundant and less costly than the one being explored at present.

He felt that solutions to the studies of raw materials were prerequisites to an expansion of ferro-alloy production in South Africa.

DISCUSSION

Mr H. Tuovinen:*

We have adopted the following circuit for ferrochromium burden. We are using ferrochromium concentrates from our own mines in Finland, and our preparation for the ferrochromium furnace is shown in the diagram given below. At first, the concentrate is ground, then filtered, pelletized, and sintered in a shaft furnace. Coke, quartzite, and dolomite are then added, and the whole charge is fed to a rotary kiln, which is heated by the off-gases from a submerged-arc furnace after the gases have been cleaned. The temperature rises to about 1200°C in this kiln. By using this method we save about 100 kWh per tonne of product.

To charge the hot products directly and continuously into the furnace we have developed a special apparatus. We have been experimenting with a simpler route in which the concentrate is fed direct into the rotary kiln with coke, eliminating the grinding, filtering, pelletizing, and sintering processes. The preheating and most of the reduction occur in the kiln.

This process has operated for a short period in our full-scale plant, and the results are very promising and show a further decrease in power consumption.

Dr J. Taylor§:

Does Mr Coetzee feel that the blast-furnace process could be an answer to the treatment of fine ore or is agglomeration necessary?

Mr Coetzee:

The agglomeration of all ores used in the blast furnace is essential. For that reason, the blast furnace offers no solution to the problem of the treatment of fine ores, including the Mamatwan ore.

Mr J. Stanko§:

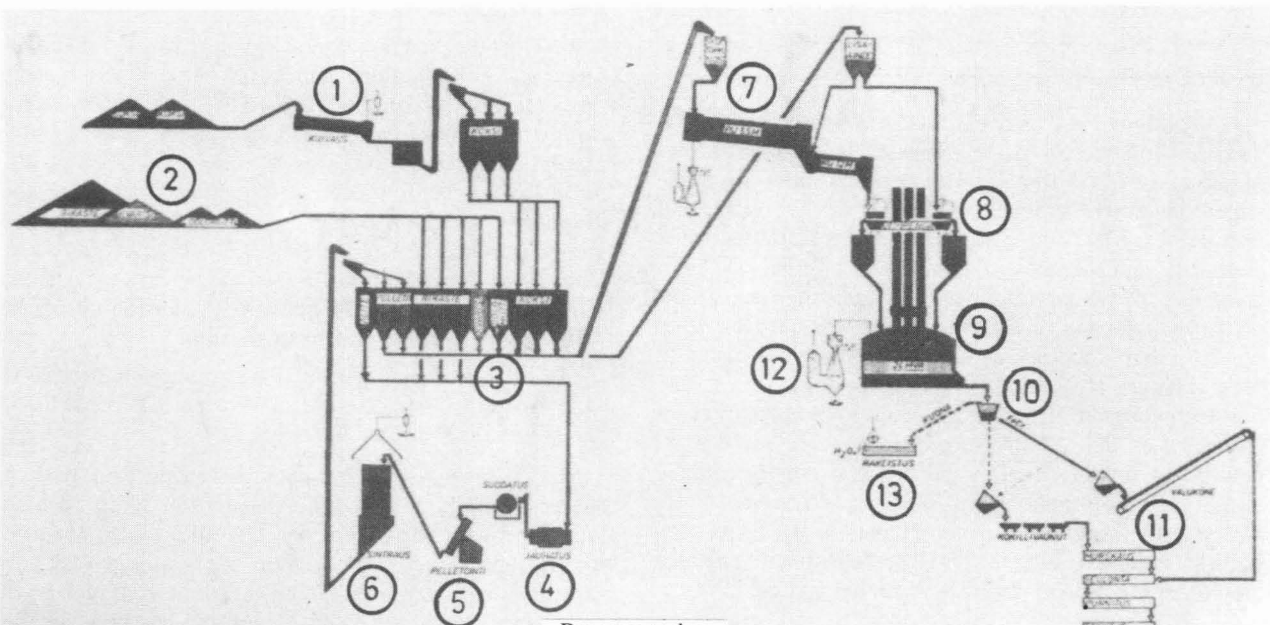
Has Amcor ever considered briquetting chromite fines?

Mr Coetzee:

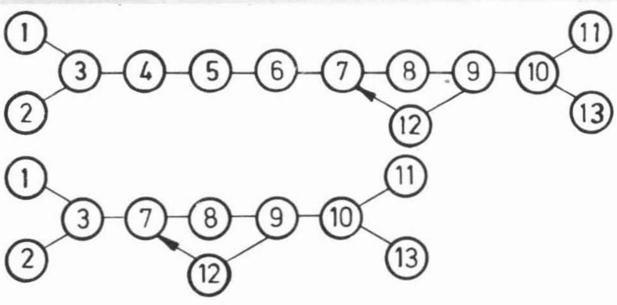
Amcor carried out unsuccessful tests on the smelting of chromite fines many years ago. The tar binder that had been used simply melted and resulted in a pot of boiling tar in the furnace. In the agglomeration of chromite ores, one major consideration is that the process should introduce the minimum amount of foreign material to the burden, particularly undesirable elements, because this material normally increases the slag-to-metal ratio tapped from the furnace, which is an undesirable feature. It can also introduce trace elements such as sulphur.

Professor D.D. Howat†:

Does Mr Coetzee consider that the low-shaft furnace will prove of value in the treatment of Mamatwan ore?



Process today



Process tomorrow

(1) Coke drying, screening
(2) Chromium concentrate, dolomite, quarzite
(3) Raw-material silos
(4) Grinding, filtering
(5) Pelletizing
(6) Sintering
(7) Rotary kiln
(8) Hot-material charging
(9) 24 MVA closed furnace
(10) Tapping
(11) Casting
(12) CO cleaning
(13) Slag granulation

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†University of the Witwatersrand, South Africa.

Mr Coetzee:

In my opinion, it will, although to prove this process will require the installation of a fairly large-scale pilot plant and will cost a considerable amount of money.

Mr P.V. Oers‡:

What is the operating voltage on the 48 MVA charge-chromium furnace and what is the voltage range?

Mr Coetzee:

The present operating voltage on the No. 4 furnace of Ferrometals Ltd is 300 V between phases, which is also the maximum voltage obtainable from the transformers. The maximum secondary voltage is used, not because of the nature of the furnace burden, but because of the electrical characteristics of that particular furnace. The voltage range is 176 to 249 V at constant current, or 249 to 300V at constant kVA.

Mr W.H. Magruder:*

I am interested in Amcor's use of coal for standard ferromanganese production. Please comment on the question of coal versus coke in regard to the furnace operating characteristics and economics.

Mr Coetzee:

The use of coal produces a somewhat higher furnace resistance than the use of coke, which is more desirable. Against that has to be set the fact that coals that are inclined to disintegrate in the hot zone of the furnace constitute a hazard to operations, leading to severe blows and even explosions. The economics is entirely dependent on the relative prices of the two materials. In South Africa, the price of a non-coking coal that can be used for ferromanganese operations is only a fraction of the price of coke breeze or coal char.

‡RMB Alloys, South Africa.

*Union Carbide Corporation, U.S.A.