

THE GROWTH OF FERRO-ALLOY PRODUCTION IN SOUTH AFRICA

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S U M M A R Y

The ferro-alloy industry in South Africa started in Witbank in 1926 and has undergone several noteworthy growth periods. The advent of argon-oxygen decarburization in the early 1960s triggered off the expansion of the ferro-chromium industry because, with this new process, Transvaal chromium ore, which has a lower chromium-to-iron ratio than most other chromium ores, became acceptable as a raw material. The oil crisis in the early 1970s precipitated an even more spectacular period of growth, during which furnaces with ever-increasing megavolt-ampere (MVA) ratings were installed. This is especially true for ferromanganese production. This latest growth phase has led to the current installed capacity of some 1200 MVA.

The growth in furnace size and rating created a number of technical and operating problems, most of which have now been solved. The solutions to these problems include the agglomeration and pretreatment of chromium-ore fines, computer-aided control, and improved electrode management.

These developments, together with the growth of the transport network in South Africa, have ensured that the industry has enjoyed an average growth rate of some 12 per cent per annum.

1. INTRODUCTION

Much has been said and written about the increasing dominance of Third World nations in the international market place. Penetration of alloys from these nations into Europe, North America, and the Far East especially has led to domestic industries being threatened by closure owing to their inability to compete economically. As a result, import duties and trigger prices have been considered at length, and have been applied in several instances.

This situation was well summarized in remarks made at the 1978 AIME Electric Furnace Conference in Toronto. Watson⁽¹⁾ mentioned in his address that imports of chromium products into the U.S.A. account for 65 per cent of all domestic consumption, manganese products for 64 per cent, and silicon products for 23 per cent. The Republic of South Africa alone is responsible for 42 per cent of all the ore and alloys imported into the U.S.A.

South Africa is particularly fortunate to be one of the few countries upon whom the advanced technological societies of the Western World are becoming increasingly dependent for their ferro-alloy requirements. It is generally accepted that South Africa possesses the world's largest known reserves of both manganese and chromium ores. Furthermore, owing to its fast-developing infrastructure, the country is in a position to extract these ores more economically than the developed nations that also possess such resources. As a result, a ferro-alloy industry has grown up around high-carbon ferro-manganese and high-carbon ferrochromium, which over the past twenty years has grown at the staggering rate of some 12 per cent per annum.

To make these developments better understood, an outline is given of the major factors that have led to this phenomenal growth.

2. ORE RESERVES

Figure 1 indicates South Africa's position in the mineral reserves of the world as accurately as can be determined at present⁽²⁾. It is of particular interest to note that South Africa is ranked first for the first seven items, four of which are essential to iron- and steel-making.

Figure 2 is a simplified representation of the major South African mineral deposits⁽³⁾. Highlighted significantly are the Transvaal system in the Sishen - Postmasburg area, which contains iron, manganese, and asbestos; the Bushveld Complex, in which the platinum-group metals, chromium, vanadium, iron, titanium, etc. are mined; and the Transvaal and Natal coal and anthracite beds.

2.1. Manganese Ore Reserves

Bearing in mind that the economically viable cut-off levels that are adopted in the estimation of ore reserves are often subjective and disregard the possibility of upgrading techniques, the South African manganese ore reserves have been estimated at some 12 000 Mt from a world total of 15 000 Mt (Table I). These reserves occur almost exclusively in two fields in the north-western Cape, which are known as the Postmasburg and Kalahari fields.

(Table I)

Manganese ore was first identified in the Postmasburg area in 1922, and in 1926 the mining division of Samancor Limited commenced operations on a limited scale. During the 1930s an increase for the demand in manganese ore led to an extensive geological search that resulted in the discovery of the Kalahari field, which is the largest known deposit of manganese in the world.

This field, with ore grades that vary from 28 to 50 per cent manganese and from 5 to 25 per cent iron with phosphorus contents of below 0,04 per cent, eclipsed the already-known Postmasburg field in economic significance. This latter field contains ores that have largely been ferruginized and that typically contain about 30 per cent manganese and 20 per cent iron. The Kalahari field itself measures some 33 km long by some 10 km wide.

2.2. Chromium Ore Reserves

It has been estimated that some three-quarters of the potential 4000 Mt of chromite in the world are situated in South Africa (Table II)⁽⁵⁾. These enormous reserves are to be found in the Bushveld Complex, which also provides South Africa with the world's largest known reserves of such materials as andalusite, vanadium, and platinum-group metals. Reference to Figure 2 indicates that the chromite reefs extend in a large circle from Rustenburg in the south-west, to Potgietersrust in the north, and to Lydenburg in the east. These reefs are roughly in the shape of an ellipse with a major axis of 400 km and a minor axis of 170 km.

An interesting fact relating to these chromite deposits is that a cut-off depth of 300m was taken in the calculation of their extent. However, it is well established that the chromite deposits extend to a depth of 600m and more⁽⁶⁾. Should this depth be used as the cut-off point, the already considerable reserves of chromite would be increased yet further and, when it is considered that rock-face temperatures at this level lie slightly above the 30°C mark, it can be readily appreciated that modern refrigeration techniques make the extraction of these reserves possible.

South Africa's chromites have an overall chromium-to-iron ratio of 1,5 to 1. When compared with the chromites of such countries as Zimbabwe or Turkey, this ratio is considered to be on the low side. However, the production of stainless steel via the argon-oxygen decarburization (AOD) process has created a significant market for the alloy produced direct from these ores. Thus, South African high-carbon ferrochromium, which has a chromium content of 52 per cent, has become perfectly acceptable to international stainless-steel makers in direct competition with the traditional high-carbon ferrochromium, which contains 65 per cent chromium and more.

This correlation is highlighted in Figure 3, which shows the introduction of the AOD process as initiating the later growth of the ferrochromium industry in South Africa.

2.3. Coal and Anthracite Reserves

A recent nationwide survey has indicated that the Republic of South Africa can lay claim to 60 000 Mt of recoverable coal and anthracite⁽⁷⁾. As a result of the ease with which these reserves can be recovered, the Republic's requirements of primary energy are predominantly coal-based, the thermal-power stations being sited at selected coalfields.

Some 80 per cent of South Africa's total requirements of electrical energy are supplied by the national power grid and, since this electricity is generated thermally, the country's requirements of energy are not subject to the variations of the international crude-oil markets. This relatively cheap energy is one of the major reasons for the cost advantage enjoyed by

South African producers in international ferro-alloy markets since the product has a high energy cost component. Reference to Table III will serve to illustrate this point.

(Table III)

South Africa's independence of external sources of energy is further highlighted by the fact that, in the Western World, Southern Africa has the largest reserves of uranium after the U.S.A. With the Koeberg Power Station in the Cape well on its way to coming on-stream, the overall energy situation augurs well for the country's economy.

Thus far the discussion has centred on the use of coal and anthracite as sources of primary energy for the generation of electricity. It is important to note that these materials also serve as reductants in submerged-arc furnaces and as grist for Soderberg electrodes, thus playing a dual role in the economy.

4. EVOLUTION OF THE SOUTH AFRICAN FERRO-ALLOY INDUSTRY

The growth of the industry, which is summarized in Table IV and illustrated in Figure 3, can conveniently be divided into three distinct phases, beginning in 1926 with the move by Rand Carbide Limited from Germiston to Witbank and the establishment there of a facility to produce calcium carbide in one 2,5 MVA and three 6 MVA rectangular furnaces. For almost twenty years, Rand Carbide was the only operator of submerged-arc furnaces in the country, and it was only in 1942 that Amcor, the forerunner of Samancor, constructed

two reduction furnaces and a carbon-paste plant at Vereeniging. Although ferro-alloys had previously been made intermittently in blast furnaces, this was the first plant to produce ferro-alloys exclusively. In 1946 Amcor built a second blast furnace at Newcastle, which, like its predecessor, produced ferromanganese intermittently. In 1951 the company chose a new site at Meyerton near Vereeniging, where two of the then-largest submerged-arc furnaces were installed. Both these 12 MVA furnaces were considerably larger than anything previously operated, and consequently, when Rand Carbide replaced several of their older furnaces with a 25 MVA unit in 1952, this huge furnace must have been treated with a considerable amount of awe.

The decade closed with the opening of two new plants, one under the Samancor umbrella at Witbank, and one belonging to Feralloys Limited at Cato Ridge in Natal. The first of these was designed to produce both ferrosilicon and ferrochromium in units of 7,5 and 15 MVA, while the latter produced ferromanganese in two 9 MVA furnaces. In 1963 Palmiet Chrome Corporation, now part of the Middelburg Steel and Alloys Limited, commenced operation at Krugersdorp, producing both ferrochromium and silicochromium in one 9 MVA and one 16 MVA furnace. A year later at Middelburg, RMB Alloys was formed and five 7,5 MVA units were commissioned. It is interesting to note that, with the development of the AOD process, RMB expanded their operations in the latter part of the 1960s to meet this opportunity, and established Southern Cross Steel for the domestic production of stainless steel.

In the same year and still on the chromium front, Transalloys (Pty) Limited was commissioned with two 4,5 MVA furnaces and two 15 MVA units. The initial

production at that plant consisted of both high- and low-carbon ferrochromium, as well as silicochromium, but depressed market conditions caused the production of chromium alloys to be discontinued, and in 1969 this plant began producing manganese alloys.

No new companies were formed during the latter half of the 1960s, but several of those already in production expanded their operations. Notable among these was Rand Carbide, which in 1965 installed a 16 MVA furnace for the production of ferrosilicon. This company no longer produces calcium carbide and has converted entirely to ferrosilicon.

The start of the third and final phase of the South African expansion began in 1970, when the total installed capacity of the Republic was 288,5 MVA. Within a mere three years this was to be doubled, and within eight years was to be quadrupled.

The decade began on a tame note with the installation of a 9 MVA furnace at Palmiet Chrome Corporation, and then in 1971/72 Feralloys built their Machadodorp plant for the production of silicochromium and low-carbon ferrochromium, and by doing so paved the way for the expansion that was to come. In 1972 Rand Carbide provided an impetus with the installation of what can be called the first of the second-generation electric furnaces, with a size of 46,5 MVA, and it is interesting to note that, until the advent of this furnace, the 25 MVA unit commissioned in 1952 was the largest in the Republic. The advent of the international oil crisis seemed to precipitate the installation of 48 MVA furnaces, which trebled the ferro-alloy capacity of Samancor, three units being commissioned in the Witbank plant and two at the Meyerton site.

It was during this time that Silicon Smelters was formed to produce elemental silicon, and three 25 MVA rotating furnaces were constructed and commissioned on the Pietersburg site of an exceptionally pure quartz deposit. Three years later, the second-last company to join the industry, Tubatse Ferro Chrome (Pty) Limited, commissioned the first of its three 30 MVA furnaces in the Steelpoort Valley of the eastern Transvaal. This plant is designed on the interesting concept that controlled screening of the primary materials is carried out and reblended ore is fed direct to the submerged-arc furnaces. This technique contrasts with that used by the last company to enter the field, Consolidated Metallurgical Industries (CMI), which was established to make use of chromium ore fines, which are pelletized with a reducing agent and prerduced before being fed to the furnaces. CMI commissioned two 32 MVA furnaces in 1977, the same year that Transalloys commissioned a 48 MVA unit for the production of silicomanganese.

In the years to the end of the decade, a significant feature was the uprating of the 48 MVA furnaces at the Samancor Meyerton Works to 75 MVA, the first of what can be regarded as the third-generation arc furnaces. This expansion in the ferromanganese production facilities of Samancor was concluded when the largest ferro-alloy furnace in the Southern Hemisphere was commissioned to produce high-carbon ferromanganese. This unit has a rating of 81 MVA.

The final event in this chapter of South African ferro-alloy history was the commissioning of the third Tubatse 30 MVA furnace, which brought the Republic's total installed MVA rating, excluding the present-day carbide facilities, to an estimated 1216 MVA.

5. TECHNOLOGICAL ADVANCEMENTS

The dramatic growth in the total installed electric-smelting capacity as shown in Figure 3, and the impressive increase in the individual MVA rating and physical size of furnace units, have necessitated a wide range of technological developments in the industry. Many of these more recent developments have taken place in South Africa as a result of the joint efforts of the ferro-alloy industry and various research-and-development organizations. Fundamental research has mostly taken place at universities and research institutes, while the applied research has been conducted at several of the local ferro-alloy plants.

5.1. The Challenge of Increased Furnace Size

The early 1970s saw the installation of the first 48 MVA electric-smelting furnaces in South Africa for the production of ferrosilicon, ferromanganese, and ferrochromium, as shown in Table IV. The furnaces for the last two processes have closed-top roofs. At first, considerable problems were encountered on many of these furnaces, partly as a result of lack of experience in operating such large closed-top units and partly as a result of certain shortcomings in the design of some of these large furnaces. Design problems arose partly from the fact that overseas-based firms had designed these furnaces without taking the nature of the local raw materials fully into account. The inter-electrode spacing, the furnace diameter, and the raw-material feed system were among the design features that had to be altered to suit local raw materials and operating conditions.

Many of these earlier large furnaces had to be rebuilt within some three to four years of their initial commissioning because of operating difficulties such as break-outs of molten slag or metal and poor electrical-performance and production characteristics. This need to rebuild the furnaces afforded an ideal opportunity for the implementation of the necessary design modifications. The design changes were largely based on the "in house" operating experience that the plants had gained during the first few years of observing the cyclic behaviour of these large furnaces. This experience was enhanced by the presence of on-line computer-based data-logging and control facilities on some of the furnaces. With the aid of these computers, a far better understanding of some of the electrical design faults of the furnaces, and especially of some of the control problems of the processes, were realized⁽⁹⁾. The major control problems associated with the large submerged-arc electric-smelting furnaces in particular are caused by interactions between the phases of the three-phase electrical circuit. The reactance-resistance relationship is a major factor in this phenomenon. Even though furnace design can lessen this problem (i.e., decreasing the reactance and increasing resistance), it was proved that a computer-based electrode controller using resistance values instead of current values was the best means of solving the problem⁽¹⁰⁾. Another control problem that was resolved was that of the inaccurate batching of raw materials. Again, this problem was especially severe in the large furnaces because of their large inventory of material (i.e., slow overall response to deliberate change in feed) and their sensitivity to unforeseen changes (i.e.,

fluctuations in the physical nature and chemical composition of the feed or errors in the weighing system itself). Control of the particle sizes of the raw materials, especially the removal of fines, was found to be another essential factor in the achievement of stable furnace operation on these large closed units. Considerable increases in production rates were realized as a result of the above improvements, thereby helping to keep the escalating production costs below the inflation rate⁽¹¹⁾.

5.2. Agglomeration Techniques

One of the major limitations of the larger ferro-alloy furnaces that had not been a severe problem on the older, smaller units was the requirement for strict control of the particle size of the raw materials. Fine raw materials (i.e., minus 6 mm) were found to be extremely detrimental not only to furnace performance but also to the safety of the furnace operation. Over 70 per cent of Transvaal chromite ore is friable, and agglomeration therefore became a subject of intense research in the early to mid 1970s. Briquetting and pelletizing are the two most popular options today. Manganese ore from the north-western Cape is physically much stronger than chromite ore, and there is no serious fines problem associated with the mining of this material. Ferromanganese furnaces, however, are much more predisposed to catastrophic eruptions than ferrochromium furnaces, and even a small content of fines in the feed material is likely to intensify the eruption problem. Sintering or briquetting of these manganese ore fines has been studied as a means of handling this problem.

5.2.1. Pelletizing of Chromite Ore

Research work on pelletizing, initiated at the laboratories of Johannesburg Consolidated Investment Company (JCI) in 1969, led to the decision in 1974 to invest in a ferrochromium plant based on the Showa Denko process⁽¹²⁾. Run-of-mine chromite-ore fines (i.e., 100% minus 6 mm, 90% minus 2 mm) cannot be pelletized direct, and the ore has to be dried and milled to about 90 per cent minus 74 μm (200#). A carbonaceous reductant - normally coke fines - is added to the ore prior to milling. At the plant of Consolidated Metallurgical Industries near Lydenburg, the milled ore is mixed with bentonite clay as a binder. A controlled amount of water is added before this fine mixture is placed in the pelletizing discs in which the "green" pellets are rolled. The "green" pellets are too weak to be charged direct to the electric-smelting furnace, and they are therefore dried and pre-heated on a grate kiln prior to being heated to 1400°C (i.e., fired) in a rotary kiln. A major local technical development was a change from costly oil-fuel firing of the kiln to the use of pulverized coal; use is now made of furnace off-gas in addition to coal to heat the pellets. Prereduction of the pellets occurs at temperatures above 1200°C as a result of the presence of coke fines in the pellet, although temperatures of 1400 to 1450°C are required to achieve reasonably high levels of reduction of the chromium oxide in the pellet. Up to 90 per cent of the iron oxide and just over 50 per cent of the chromium oxide can be reduced in the kiln. The hot (1000°C) prereduced pellets are fed to the electric-smelting furnace together with unheated fluxes and additional carbonaceous reductant to make up the stoichiometric requirements.

The above pretreatment process results in about a twofold saving in the electrical energy in the smelting operation, namely 2 as against 4 MW.h/t. The metal output is virtually doubled from a given furnace at the equivalent megawatt load. This saving of electrical energy is the major advantage of this process, especially in countries where the cost of electricity is high. Other advantages include the ability of this process to utilize finer raw materials (which are less costly), and the higher overall recovery of chromium, than for the more conventional smelting processes. The above cost advantages must, however, be weighed against the costs of the milling, pelletizing, drying, and prereduction of the chromite ore. The cost of milling could be substantially offset if, as seems likely, chromite ore from the UG-2 Reef can be used instead of run-of-mine ore fines⁽¹³⁾. The UG-2 ore is soon to be processed for the recovery of platinum-group metals.

It was the research work at JCI laboratories that gave the confidence to the industry to proceed with this rather technically involved prereduction pelletizing route. Several alternative pelletizing processes are used abroad, but this is the only one used in South Africa.

5.2.2. Briquetting of Chromite Ore

In the mid 1970s Middelburg Steel and Alloys and Samancor studied the possibility of various pelletizing routes. A programme of laboratory and pilot-plant work was undertaken by the National Institute for Metallurgy

(now the Council for Mineral Technology - Mintek)⁽¹⁴⁾. This research work was successful, but firstly Middelburg Steel and Alloys and then Samancor abandoned the idea of a pelletizing plant and opted for the briquetting route instead. The following factors influenced this decision⁽¹⁵⁾.

- (1) the lower capital cost of a briquetting plant and the higher capacity than for other agglomeration processes,
- (2) the low operating cost of agglomeration by the briquetting process,
- (3) the minimum adaptation required to the raw-material feed system to the furnace, unlike that required for the charging of hot pellets,
- (4) the absolute control in the briquetting process over the size of the agglomerate, and the easily changed size of the briquettes, which can easily be adapted to suit the requirements of furnace resistivity.

Another advantage of briquetting is the fact that chromite ore fines do not require milling to a fine particle size, as is the case for pellets. The ore is merely dried and screened to minus 8 mm, although some producers prefer a particle size of minus 4 mm. This finer size sometimes requires some coarse milling prior to screening. The greatest proportion of chromite ore in briquettes is minus 2 mm. The most widely used binder is a combination of hydrated lime and molasses.

The ore, molasses, and lime are mixed thoroughly before the material enters the briquetting rolls, and the briquettes are stockpiled to permit curing to take place. Chromite-ore briquettes can generate up to 25 per cent fines on being handled, and these fines must be removed and recycled.

Research work to develop the process was undertaken jointly by Palmiet Chrome Corporation and Mintek from 1974 to 1976, during which time a 9 MVA furnace was successfully operated on briquettes produced from a 15 t/h pilot plant. Based on these findings, Middelburg Steel and Alloys installed a 250 kt/a briquetting plant in 1976 to feed the first of its two 30 MVA semi-closed electric-smelting furnaces.

In 1975 Samancor's Witbank plant, Ferrometals Limited, installed a briquetting plant, which was subsequently expanded in 1979 to give an annual production capacity of some 700 kt.

Research-and-development work has continued, and it has been shown that reductant fines, as well as off-grade metal fines, in chromite-ore briquettes can be absorbed into the furnace. The use of alternative binders has also been investigated, e.g., phenol pitch blends and calcium ligno sulphonate liquor.

Despite their few disadvantages, briquettes account for the major proportion of the agglomerated chromite ore that is fed to ferrochromium furnaces in South Africa. These include the limited availability of molasses, especially in the long term, the reasonably high phosphorus content of molasses and its adverse influence on metal grade, the low physical strength of briquettes in the temperature range 750 to 1000°C, and the high loss of unreduced chromite spinel in the slag phase, i.e., the poor chromium recovery. Research and development are continuing into these problems.

5.2.3. The use of Run-of-mine Chromite Ore

Small electric-smelting furnaces of between 9 and 15 MVA have been shown to be operable with up to 100 per cent chromite ore fines, but the larger, and especially the closed-top, furnaces cannot tolerate more than a maximum of 10 per cent minus 6 mm material in the feed. The Tubatse Ferrochrome Plant at Steelpoort, one of the most recent ferrochromium plants in South Africa, has been specially designed to operate on run-of-mine material (i.e., 70 per cent chromite ore fines and 30 per cent lumpy ore)⁽¹⁶⁾. The development work for this plant was carried out in the U.S.A. by Union Carbide, but the implementation of the know-how took place in South Africa. The objective of this development was to enable these furnaces to operate successfully at some 22 to 24 MW on run-of-mine material. Skilful manual operation of these open-top furnaces is essential to ensure stable operation. The avoidance of agglomeration of the raw materials reduces costs, but the loss of the benefits of a more homogeneous feed must be borne in mind.

5.2.4. Sintering of Manganese Ores

South Africa has vast reserves of manganese ore, which are conservatively estimated at some 12 000 Mt. Unlike its chromite ores, the physical quality of South African manganese ores is very good, and no serious fines problems are therefore encountered. However, the manganese ores can contain water of crystallization, carbonates, and higher oxides of manganese. The serious furnace eruptions that have been experienced on ferromanganese electric-smelting furnaces are thought to be partly due to the presence of these constituents. (This subject was discussed in detail at the Thirty-eighth Electric Furnace Conference, Pittsburgh, December 1980.)

Tests on large furnaces using sintered feed have resulted in more stable furnace operation. To date, however, there is no sinter plant for ores to be used in the production of ferromanganese, and the possibility of briquetting manganese ore fines is currently being studied.

The grade of ferromanganese metal that can be produced is directly related to the manganese-to-iron ratio in the ore. Some ores are of a low grade, and development work on their upgrading is being carried out. Some additional ore fines are generated in this process, and these fines also need to be agglomerated.

5.3. Computer Control of Ferro-alloy Furnaces

With the advent of larger electric-smelting furnaces, it was soon realized that improved control was necessary, especially if the production was to be optimized. In 1974 some ferro-alloy plants, in collaboration with Mintek, embarked on projects to install computer-based data-logging and control systems^(11,17). Aspects of this work are still being pursued with almost all the South African ferro-alloy producers. The key factors in the selection and installation of the computer system were reliability and price of the hardware, local support for the system, flexibility and memory capacity of the system for research and development, and suitable environmental protection of the delicate computer components.

The computer systems were at first used essentially for data logging on ferrochromium plants and subsequently on a ferromanganese plant. Certain control functions, e.g., raw-material batching and electrode-power regulation, were studied. Once the benefits had been demonstrated and the control

philosophies had been fully developed, these control functions were implemented on separate "stand alone" microprocessors to ensure the highest possible reliability. Complementary to these, improved metallurgical control philosophies were developed after a considerable research-and-development effort. Computer programs were written to perform material and heat-balance calculations, seeing that the successful operation of a ferro-alloy furnace depends, above all, on the correct proportioning of raw materials. The ratios for the blending of raw materials are calculated from the chemical analyses of these materials and from a knowledge of the required grade and specification of metal. Furthermore, a slag having a composition that can be identified with good furnace behaviour must be achieved by the blending of suitable fluxes, and the stoichiometric amount of carbonaceous reductants must also be added. The rapid calculation of blending ratios using computer systems, and the controls afforded by batching and electrode-control microprocessors, have enabled many of the ferro-alloy plants to achieve a much more stable operation in their large ferro-alloy furnaces than before. Increased production and profitability are the natural outcome of these developments.

5.4. Decarburization

The development in 1967 of the AOD process⁽¹⁸⁾ for the production of stainless-steel did more to establish the viability of producing a high-carbon ferrochromium with only a 50 to 55 per cent chromium content (rather than the only acceptable alloy up to that time, with 65 to 70 per cent chromium) than any other single development. This invention was made by Union Carbide in the U.S.A., and it has greatly favoured the production of high-carbon ferrochromium in South Africa from so-called "low-grade" Transvaal

chromite ore.

The AOD process has substantially decreased the relative demand for silicochromium and low-carbon ferrochromium, the former ingredients of stainless steel. Most ferro-alloy plants built in South Africa since 1970 have thus been able to take advantage of the demand for high-carbon ferrochromium and have avoided the mistake of designing what may have been obsolete plants.

In the AOD process, the carbon level in the chromium-iron alloy is normally lowered from between 2 and 3 per cent to less than 0,5 per cent. Chromium losses are limited by the use of rapid-blowing techniques and temperature control, but some silicochromium is used to scavenge any chromium oxide from the slag. Southern Cross Steel is the only ferro-alloy stainless-steel plant in South Africa with an AOD facility. Its capacity is currently being expanded to meet increased demand.

The decarburization of high-carbon ferrochromium itself has been studied both abroad and at Middelburg Steel and Alloys, and the carbon content of the alloy can be lowered from between about 7 and 7,5 per cent to normally between 4 and 5 per cent⁽¹⁹⁾.

Manganese alloys are not generally used in the same high concentrations in iron-based alloys as in chromium alloys, and thus the carbon content of the ferro-alloy addition is not so critical. Techniques have been developed locally and overseas for the decarburization of high-carbon ferromanganese, but so far the process has not been widely practised, and not at all in South Africa, although the future does hold some promise in this regard⁽²⁰⁾.

6. CONCLUSIONS

Currently the world steel markets are moving through a strong recessionary period, and, even in the unlikely event of this changing dramatically in the short term, the same growth rate as over the past ten years cannot be expected. Instead, a period of consolidation and refinement can be expected, with the older and less economic furnaces being shut down and the production capacity absorbed into the larger, more efficient units.

Projections of the growth rates of tonnage alloys correlate closely with those of their respective steel tonnages, and augur well for countries such as South Africa that have the necessary raw materials and infrastructure. Even in the event of a move away from high-carbon to low- or medium-carbon varieties dictated by a changing steel technology, countries having these production factors will remain in strong positions since the techniques for the manufacture of other varieties of carbon are well known. The Republic of South Africa is one of the largest producers of elemental manganese and could, if needs be, move into the field of elemental chromium production, thus covering the broadest possible spectrum.

Current and future research in South Africa is expected to take a twofold approach to the continuing development of the ferro-alloy industry.

In the first place, the production process in large submerged-arc furnaces will be understood in a wider context as ongoing investigation reveals more and more facts relating to the interior of the furnaces, particularly in regard to the metallurgical-electrical relationships. Computer control of the raw-material feed by accurate and scientific blending, as well as control of the Soderberg electrode-baking mechanism, are but two of the

approaches that are in the spotlight. An understanding of these factors will determine better performance, better economics, and therefore greater competitiveness by South African products.

In the second place, current and future research is aimed at alternative processes for the production of alloys. As an example, announcements have already been made to the media regarding the promise held by the plasma smelting of ores.

In summary, the competitive position of the Republic of South Africa's ferroalloys can be expected to remain strong, particularly when the facts presented in this paper are compared with the costs of transporting ores, together with unwanted oxides and gangue material, to First World countries, as well as the diminishing reserves and escalating costs of labour and energy in those areas.

7. ACKNOWLEDGEMENT

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