8th International Ferroalloys Congress Proceedings

June 7-10, 1998
Beijing, China

Organized by
The Chinese Society for Metals

China Science & Technology Press

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PREFACE

The International Ferroalloys Congress is an important event in the field of ferroalloys production. It provides a forum for the discussion on technology progress and the exchange of views on market development. We believe the success of INFACON 8 will certainly promote the prosperity of ferroalloys industry.

The high light of INFACON 8 is the economization of energy and resource, environment protection and market stability. They are deeply concerned by all ferroalloys producers in the globe. The papers published in this proceedings have shown the progress which had been achieved in these aspects in the past few years.

The reports at the plenary sessions are included in the first section of the Proceedings. The technical papers are grouped according to the sequence presented in the sessions. They are Environmental, Ferrosilicon, Ferrochromium, Ferromanganese, Fundamental Modeling and Control and Special Topics. The last section covers those special topics in electrode, casting, refractory, special alloys etc.

All accepted papers have been refereed and edited by INFACON 8 Technical Committee. It should be pointed out that the principle of the editing work is the authors shall be responsible for the reliability of his paper. The proceedings was pre-printed according to the received camera-ready manuscripts. Those papers, which were not delivered before the deadline, had not been able to be collected in the proceedings. Some of them, however, are printed in loose leaves.

Many thanks are due to all the authors and the invited speakers for contributing their papers and for supporting the congress.

DAI Wei
Chair
Editorial Committee of INFACON 8 Proceedings

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Developments in Technology for Ferrochromium Production

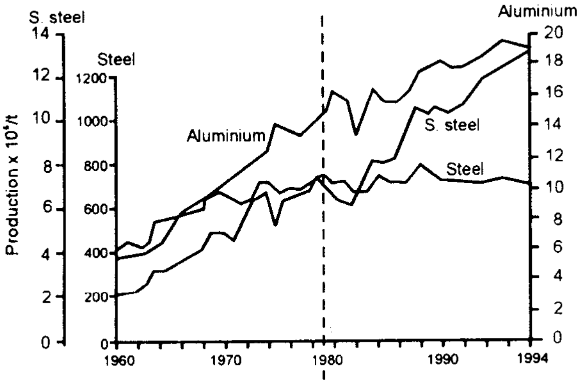
Aidan M Edwards

Chairman: International Committee on Ferroalloys
President: Mintek, Pvt Bag X3015, Randburg 2125, South Africa

In recent years it has been predicted that the world is leaving the metals age and that, in future, the importance of metals will decline as we enter the realm of synthetic products and inorganic composites.

Whether these forecasts are true or not, the metals industry is still showing strong growth, and we can safely assume that sales will continue to flourish in the foreseeable future. For example, the stainless-steel industry has continued to expand at a compounded 4.1% per annum since 1974, and at a much greater rate than its rival, aluminium. In 1960 only 2 million tons of stainless steel and 4 million tons of aluminium were produced, whereas today's production levels are greater than 16 and 20 million respectively. Indeed, more nickel, chromium, aluminium and magnesium units have been exploited in the last 25 years than at any previous time in history.

WORLD PRODUCTION OF STEEL, STAINLESS STEEL, AND ALUMINIUM



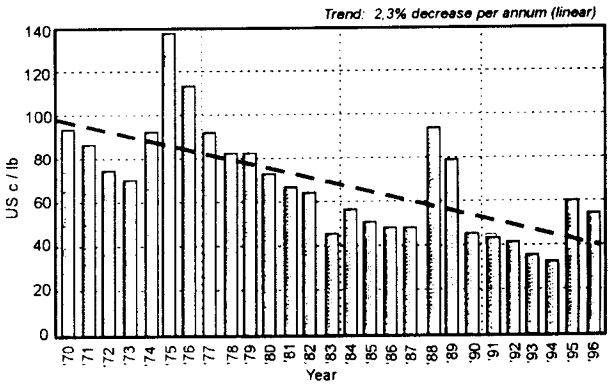
Growth, 1960 - 1974		Growth, 1974 - 1994	
Steel	5,0% p.a.	Steel	zero
S. Steel	8,2% p.a.	S. Steel	4,0% p.a.
Aluminium	8,6% p.a.	Aluminium	2,0% p.a.

The very purpose of INFACON is for technical experts to share their experiences in order to ensure that the raw materials feeding the stainless-steel and related industries are produced cost-effectively, thereby securing the future well-being of the industry.

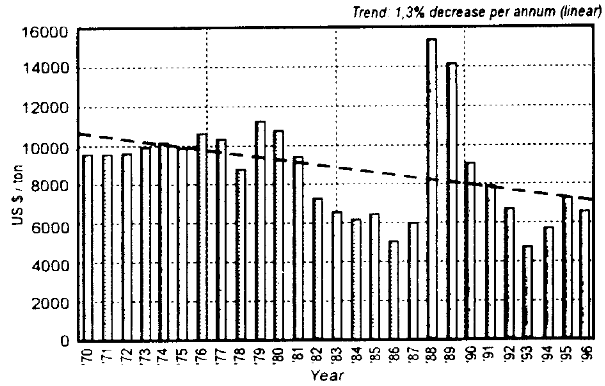
As real prices continue to fall in this highly competitive environment, new technologies must continuously be developed for the industry to remain profitable.

Since 1970 the real prices of HC ferrochromium and nickel – the principal alloying constituents in stainless steel – have fallen by 57% and 31% respectively. As a consequence the real price of 304 stainless steel has fallen by a massive 60%. Within this scenario one can appreciate the need for the industry to tighten its belt.

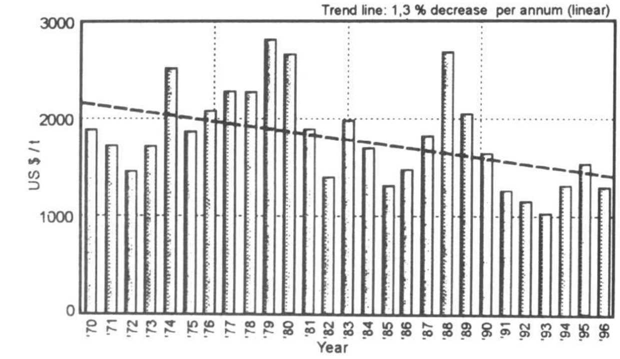
CHARGE CHROME : REAL PRICE - (1990 = 100)



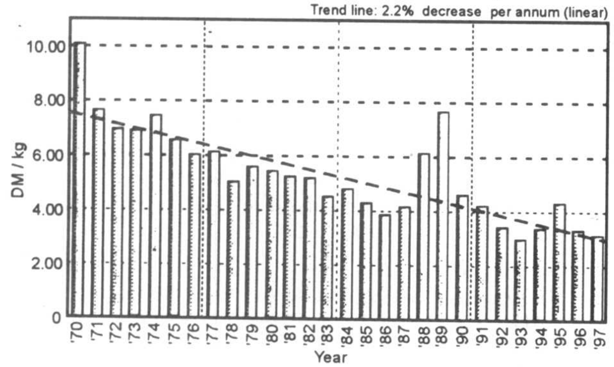
NICKEL REAL PRICE, $ / ton - (1990=100)



ALUMINIUM : REAL PRICE (1990 = 100)

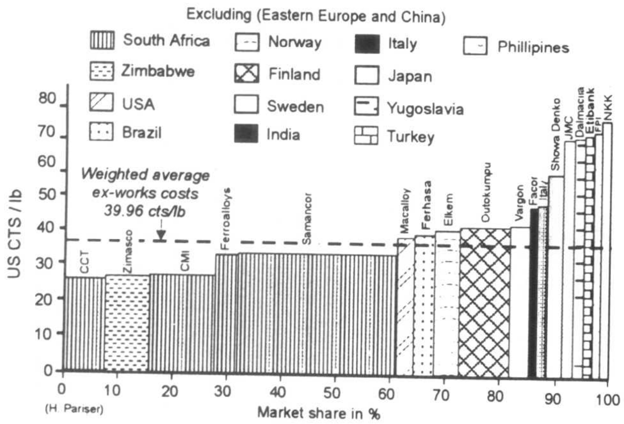


STAINLESS STEEL TYPE - 304: REAL PRICE (1990 = 100)



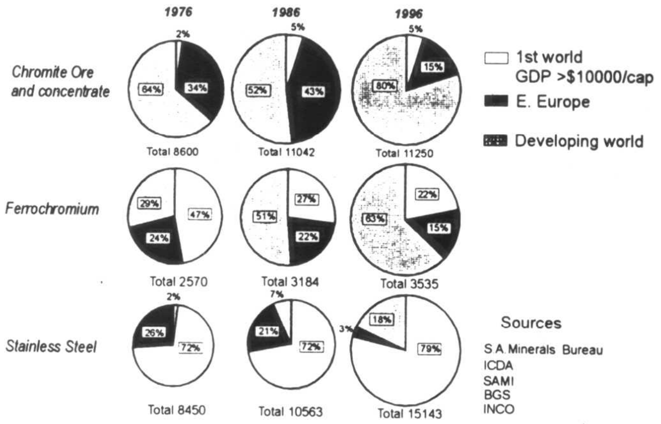
Pressure to remain competitive has resulted in a persistent quest to improve technologies and, at the same time, to relocate operations near the source of the raw material while taking cognizance of the price of the critical ingredient, electrical power, and other forms of energy. Historically, ferrochromium was produced exclusively in the First World, but these factors, compounded by environmental requirements and the need to replace obsolete installations, have led to an inexorable drift away from the developed world. The UK, Germany and France no longer produce ferrochromium; the formerly dominant industries of Japan and the USA are but shadows of their former selves, and others (such as Italy, Sweden and Finland) are under threat.

COMPARISON OF FeCr PRODUCTION COSTS ex WORKS
March 1995



A look at developments over the past 20 years paints an interesting picture. In South Africa, for example, only 42% of the chromite concentrate mined was transformed into ferrochromium in 1976. A decade later this figure had grown to 65%, and by 1996 it had reached 76%.

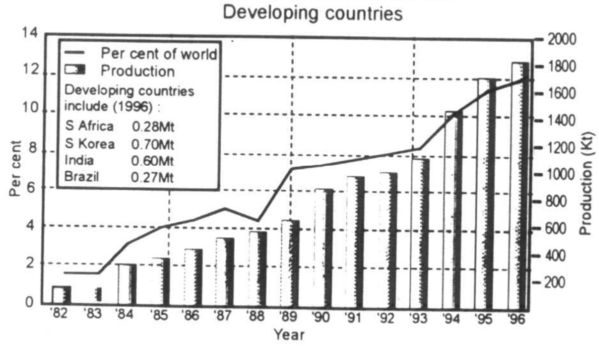
PRODUCTION OF CHROMITE, FERROCHROMIUM AND STAINLESS STEEL (x 10 tons)



Expressed differently: in 1976 only 22% of all ferrochromium was produced in the developing world. This proportion grew to 50% in 1986, and 66% in 1996. Whereas total ferrochromium production has risen from 2.2 million tons to 4 million tons over the past 20 years, the tonnage produced in the developed countries has fallen from 1.72 to 1.36 million tons. South Africa's exports of chromite concentrates for conversion abroad have remained steady at about 1 100 000 tons per annum for the past 25 years.

It is therefore probable that virtually all newly-installed ferrochromium capacity to meet the ever-growing demand for stainless steel will be located in South Africa and other chromite source countries. In parallel with such developments, the propensity to construct new stainless-steel facilities will be greater in ferrochromium-producing countries, and already plans are afoot to start such new facilities both in Zimbabwe and South Africa. The impact of geographic relocation of the stainless-steel industry is still in the early stages, but South Africa's share of the developing world's stainless-steel production has already grown from 4% to 14% in 1996. South Africa could within the next decade become one of the world's major producers of stainless steel.

STAINLESS STEEL PRODUCTION
Developing countries



The location of an industry is ultimately decided by economic factors. South Africa's rise to prominence as a ferrochromium producer has been marked by a series of innovations in production technology.

Perhaps the greatest impact on ferrochromium process technology was caused by the dramatic technological breakthrough by Union Carbide in 1970. Until the advent of the AOD little, if any, refining was implemented in the process of stainless-steel manufacture. The principal demand was for a low-carbon product which was supplied with as high a chromium-to-iron ratio as possible – essentially higher than 3. South African chromites were not popular, and often had to be blended with high-ratio Zimbabwean chromite concentrate. It was in the early 1970s that the term, charge chrome, as distinct from high-carbon [HC] ferrochromium, was coined by the late JJ Coetzee of Amcor (the precursor to Samancor). Thanks to the AOD and the VOD, this product rapidly gained in popularity by virtue of its cheaper price, in spite of a chromium content only marginally greater than 50%, a chromium-iron ratio of about 1.6, and a high silicon content. This newly-introduced product would not have gained acceptance, had such refining technologies not been introduced into the stainless-steel manufacturing process.

The next development in South Africa was led by the fact that, although domestic chromite was cheap by international standards, lumpy material was available only in small quantities, and even this was commonly referred to as 'friable lumpy'. Eighty per cent of South African ores occur in a finely divided form – not ideally suited for the traditional submerged-arc furnaces used for ferrochromium production.

During the 1970s, numerous programmes were undertaken to agglomerate ore fines either by briquetting or pelletising. This was followed by research into the pre-reduction of pelletised chromite concentrates, which culminated in the SDK process in Japan which was subsequently applied by CMI in South Africa in 1977. It is interesting to note that during the time that I worked for JCI, similar research was undertaken in South Africa – initially with the intention that pre-reduced pellets would be exported to both Japan and Europe. However, it was eventually realised that it would be more cost-effective to feed the pre-reduced pellets directly to a submerged-arc furnace, thereby effecting major savings in electrical energy. It was at this stage, following the revival of the ferrochromium industry in 1973, that JCI decided to work in partnership with Showa Denko and introduce their then-proven technology at Lydenburg in South Africa. This was the first time that cheap pulverised coal was used to reduce chromite in a rotary kiln.

During the 1970s major expansions took place in South Africa. Not only did CMI come on stream in 1977, but the then Union Corporation Mining Company commissioned the Tubatse operation at the source of raw material at Steelpoort, and the Anglo Vaal group (through Feralloys) commissioned a low-carbon ferrochromium operation in Machadodorp. In hindsight, this was clearly an incorrect decision and the operation was subsequently converted to charge chrome, although Feralloys retained a foothold in the diminishing low-carbon market until 1991.

The transformation of the market from high chromium/iron ratio ferrochromium to the cheaper low-ratio charge chrome product, using Transvaal chromite, was now well-established.

It was also during this period that further operations were commissioned in the developing world and in countries where chromite was mined, namely at Etibank in Turkey and at Ferbasa in Brazil. These were to be followed by the Facor operation in India and in the Philippines. Concomitantly drastic cutbacks took place in Europe and in the USA, where a cost squeeze was experienced on account of the fact that raw material was imported and the costs of electricity were inordinately high. The energy crisis of 1973 served to accelerate the transfer of operations to the developing world. Since the mid-1970s, the price of charge chrome has, in real terms, fallen from around $1 per pound to current levels of less than 50c per pound. Southern Africa has emerged as the most cost-effective sector of the world, having been able to maintain operating costs at less than 40c per pound. (One may well speculate that the much-reduced ferrochromium prices have had the beneficial effect of causing the stainless-steel business to achieve its impressive growth – exceeding that of aluminium, its main competitor.)

This low production cost has been made possible by a number of innovative technologies having been developed principally in the Southern African region. Mintek itself has played a prominent role in researching the development of new and improved technologies in support of the industry.

Since lumpy chromite is relatively scarce in relation to the so-called 'sugary' or 'friable lumpy' concentrate, which occurs virtually exclusively in this form in South Africa, Mintek aggressively undertook research and development of D.C. arc plasma-smelting technology. This culminated in the commissioning of a 16 MVA single-electrode D.C. open-arc plasma furnace in 1984 at Palmiet Ferrochromium, then a subsidiary of Middelburg Steel & Alloys, which is now incorporated in Samancor. The rights to this technology were acquired from Mintek, and today Samancor operates a 40 MVA furnace at this site.

Although savings of electric power consumption are doubtful, this facility has obviated the need to agglomerate fines, which are fed directly into the melting zone via a single hollow electrode. Furthermore, low-phosphorous coal is used as reductant, rather than expensive metallurgical coke. Increased chromium yields are achieved. This technology is now widely utilized in a number of other applications developed by Mintek, such as the production of titania slag, and zinc from steel-plant dust and lead blast furnace slags. An enormous potential lies in the treatment of nickel-bearing lateritic ores for the production of ferronickel.

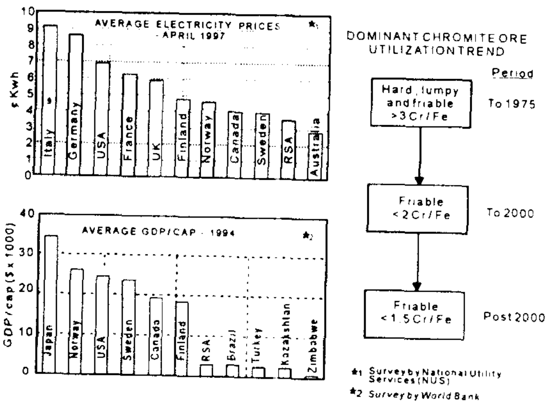
The Minstral furnace controller is another innovative development, which Mintek first introduced to industry at Samancor in 1980. This technology, which allows for effective instrumental control of submerged-arc furnace operations, is now widely used by industry, and already 24 Minstrals are in operation in many parts of the world. The technology is constantly being improved and is currently used not only in the production of ferrochromium, but also for calcium carbide and ferromanganese. It has been estimated that through its application, production throughput has been improved by as much as 20%.

Middelburg Steel & Alloys, the first company to use plasma smelting technology, also pioneered the CDR process, based on the Krupp direct-reduction process. This process is similar to that employed by Showa Denko and CMI in that the CDR kiln is designed to pre-reduce the feed before it is charged into an electric furnace. However, the material does not have to be agglomerated before reduction, and up to 95% pre-reduction of chromite fines can be achieved at temperatures of over 1500°C. It is claimed, furthermore, that by using cheap low-grade coal and oxygen, electrical energy costs can be reduced by as much as 75% compared with the conventional submerged-arc furnace (around 4000 kWh per ton of alloy produced). The metallized kiln product can be charged hot to a dedicated melter, or allowed to cool and be charged to a conventional submerged-arc furnace. After a severe operational problem with the downstream melter during commissioning necessitating a lengthy shut-down, Samancor recommissioned the plant in 1997, incorporating a 62 MVA D.C.-arc melter/smelter. The efficacy of this process has yet to be demonstrated.

Samancor, in conjunction with Outokumpu, is also constructing a 520 000 tons per annum pelletising and sintering plant and preheating shaft kilns at the Witbank Ferrometals works.

Chromium units are also produced as a by-product of processing the platiniferous UG2 orebody of the Bushveld Complex. Unfortunately this ore has not been generally used for ferrochromium production because of its low chromium-to-iron ratio viz 1.35. As mentioned earlier, there has been a trend away from the traditional high 3:1 ratio of ferrochromium to that of charge chrome where the chromium content requirement should be greater than 50%. When UG2 chromite is reduced by conventional means, an unacceptable grade of about 46–47% chromium results. However, with the greater efficiency of plasma-smelting and with pre-reduction it is possible to meet the requirements of charge chrome, provided that Cr recoveries of more than 90% can be achieved.

ECONOMIC CONSIDERATIONS



There can be little doubt that UG2 chromite (currently a waste product of the platinum industry) will be used in the future as a major source of chromium units, particularly if South Africa's stainless-steel industry continues to expand. High transport costs could be avoided, and the product would represent a source of free iron units and would be cost-effective in spite of the requirement to remove greater quantities of carbon during conversion. The UG2 chromite is very finely grained and would lend itself well to processes suited to the treatment of fines, either through plasma-smelting, agglomeration, or direct reduction of fines, pellets or briquettes.

The UG2 by-product constitutes a vast resource of cheap chromium units. About 200 000 tons per annum could be supplied by the platinum industry, assisting the South African ferrochromium industry to maintain its dominant position in the years that lie ahead.

For the foreseeable future the stainless-steel industry will require lumpy ferrochromium as feed-stock. Traditional methods of breaking the cast ferrochromium are both messy and wasteful. This problem was overcome somewhat in the 1970s with granulation processes, which resulted in a relatively fine product to handle. Recent developments by CMI have resulted in a coarser granulated product (up to 35mm) being made available to the market by applying a more controlled granulation technique. Mintek has improved the technique further, and the 'blobulator' process has been demonstrated on a wide range of ferroalloys and steels. Not only is the product easy to handle, but fewer fines are generated.

The recent deterioration of ferrochromium prices has resulted in increased attention being given to reclamation of entrained ferroalloys from slag dumps. Mintek has played a major role in promoting this technology by using jigs modified for this purpose. It is estimated that currently 250 000 tons of ferrochromium and ferromanganese are being recovered from slag dumps each year at costs appreciably less than the cost of producing alloy from virgin material.

In the future, trends in the industry may be such that chromium may be purposely concentrated in slag, ultimately resulting in two products: an iron-rich product, relatively low in chromium content, and a high-grade chromium-iron alloy following reduction of chromium and iron retained in the slag.

Studies have been under way for many years, following initial work in Japan, with the view to producing stainless steel directly from ore. To date it does not appear that such production techniques will present any meaningful threat to the ferrochromium industry. But then, technology is consistently on the move.

It seems to be reasonably certain that world demand for stainless steel will continue to grow at a healthy rate, and it will be necessary to supply an additional two to three hundred thousand tons of ferrochromium per annum into the marketplace. However, it is also possible that prices of ferrochromium will continue to fall in real terms, and that the industry will be kept on its toes in its quest to improve efficiencies and develop new techniques. Perhaps the silver lining is the fact that lower prices result in a concomitant increase in demand for stainless steel. We may indeed wonder how large the stainless-steel market would be today, had the price of ferrochromium been sustained at say 80c per pound, as it was in real terms 20 years ago.

Strategic Issues in the Ferroalloy Industries

Christopher Stobart

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Introduction

All properly run businesses require medium and long term plans, based on strategies designed to achieve the objectives set by their owners. Plans require forecasts, and forecasts require assumptions to be made. I do not need to remind managers from the ferroalloy industry that forecasts of commodity markets are frequently wrong; and when they prove to be wrong, the reason is generally that they were based on assumptions that proved to be incorrect. The developments that forecasters fail to predict may not be totally unexpected, but the timing and the speed or scale of events may well be a surprise.

unsatisfactory to base a business plan or a corporate strategy upon a single forecast of supply, demand and price for the product in question. If the forecast turns out to be wrong, the plan or strategy is also likely to be mistaken.

A solution sometimes used is to provide a high and low variant in addition to the central forecast. However, this does not eliminate the problem. It only means that the range of uncertainty increases as the forecast extends into the future. High and low forecasts will also be useless or misleading if the fundamental assumptions underlying the central forecast prove to be completely wrong.

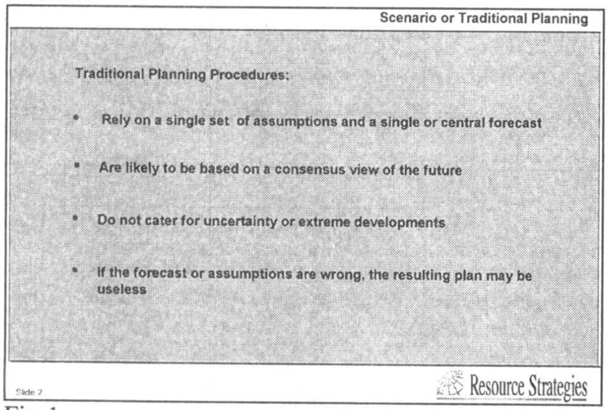

Fig.1.

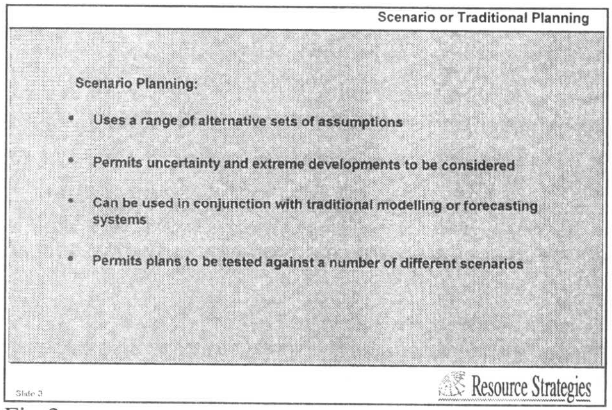

Fig.2.

For example, how many forecasters correctly foresaw the sharp contractions that we have seen in South-East Asian economies in the past nine months? How many foresaw the collapse of the Former Soviet Union, and all the economic repercussions that flowed from that event? How often have earlier forecasts been proved wrong because the analysts in question made the wrong assumptions about economic growth rates, energy prices or exchange rate movements?

These examples show how very difficult it is to make accurate forecasts of a commodity market. Nevertheless it is essential to have a view of likely future developments, as a basis for a corporate strategy and a medium or long term business plan. In Resource Strategies, we frequently assist companies with their planning exercises, but we find it unrealistic and

The way to escape from this dilemma, in my opinion, is to use scenario planning. The concept is simple. Instead of using a single set of assumptions as a basis for a forecast or a business strategy, we develop a number of scenarios covering a number of different economic, political or technical developments. These can be used to generate a range of forecasts. More importantly, the company's business strategy can be tested to see how well it can accommodate each of the scenarios. The strategy can then be adapted or improved to ensure that is robust enough to stand up to the range of different scenarios that are considered likely.

Of course, the scenario planner may also fail to foresee the trends that actually develop, and the conditions in which his company must operate. However, he has a much better chance of foreseeing developments correctly because he can develop as many scenarios as he likes, or at least as many as he can practically handle. He can include apparently extreme developments, such as the collapse of the Soviet Union or sudden economic declines across South-East Asia, without necessarily selecting them as the basis for a single or central forecast. In other words, scenario planning allows and even encourages the company formulating its strategy to consider a wide range of possibilities, including extreme or even unthinkable developments. The company can then ensure that its plan or strategy is strong enough to stand up to extreme or unlikely possibilities, and is not based only on the apparently safe consensus forecasts that the majority of his competitors will be using.

So much for the theory. In this paper I want to propose some scenarios that may affect the development of the ferroalloy business over the next five years or so, and examine potential strategies that companies in the industry might adopt, to see which ones appear the most secure or robust. Obviously, in a paper addressed to the industry as a whole, it is not possible or desirable to consider the strategies and the strengths and weaknesses of individual companies; that is an exercise that we would conduct only in confidence with an individual client company. However, we can consider some generic strategies and, I hope, produce some insights which may be of value in showing how individual companies could benefit from a scenario planning approach. First, however, we have to understand the recent history of the major ferroalloy industries, and the position from which they start today. To keep this paper within manageable limits, I have confined my attention to the manganese alloys and ferrochrome.

Recent Features of the Ferroalloy Industry

Manganese Alloys

Since well over 90% of manganese alloy consumption is accounted for by the production of steel, the market for ferromanganese and silicomanganese is determined by the rate of growth in steel production and the amount of manganese units used on average per tonne of crude steel produced.

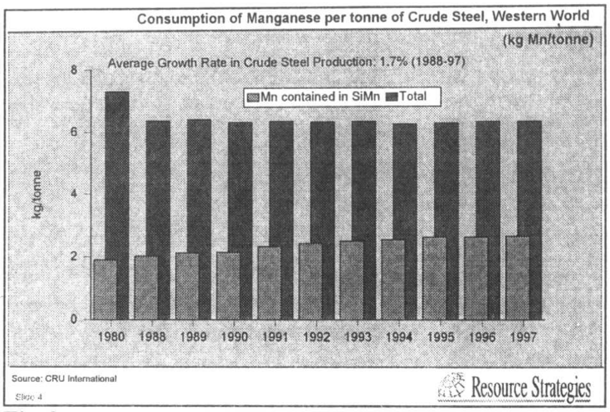

Fig.3.

In the Western world, crude steel production has grown at an average rate of 1.7% in the past decade, though with peaks of close to 7% in 1997 and troughs of -1.4% in the recession of the early 1990s. The unit consumption of manganese fell dramatically in the 1970s, when open hearth furnaces were being phased out in the Western world. In 1980 the average figure was 7.3kg per tonne. In the late 1980s it had fallen to around 6.4kg and has remained at or just below that figure ever since. In China and the CIS, we believe that the average figure is higher but it should gradually approach the Western average level. In the Western world little change is expected in the future.

The one noticeable trend is the steady increase in the consumption of manganese in the form of silicomanganese. This has been caused by the growth in electric arc steel-making and also by a trend towards the production of steels with low carbon contents.

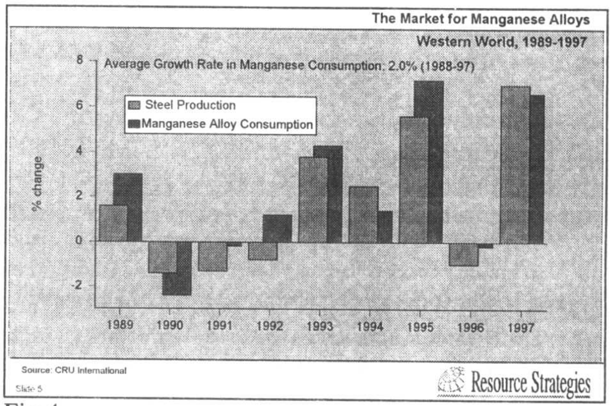

Fig.4.

The growth in demand for manganese alloys in the Western world has followed the changes in crude steel production quite faithfully, and since 1989 has averaged 2.0% per year. There have been years when the market has grown by as much as 6-7%, but over the medium term this is a market which is not likely to generate major surprises, at least on the demand side.

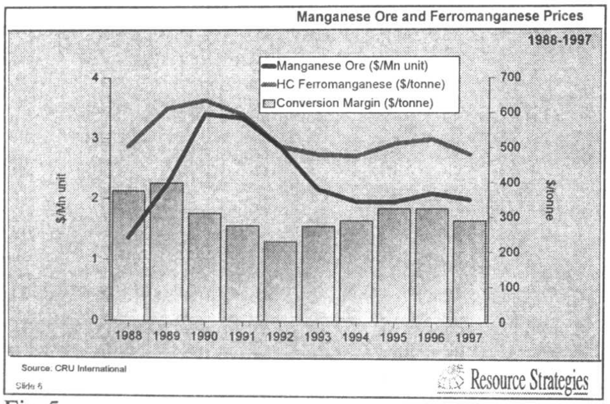

Fig.5.

Market prices, on the other hand, have shown more variation than the slow rate of growth in demand might initially suggest. One of the main driving forces is the price of manganese ore, which in 1989-90 was in tight supply. However, since 1994 both ore and high carbon ferromanganese prices have on average been quite stable.

The bars at the foot of the chart give an indication of the average conversion margins available in the industry as a whole, defined as the difference between the average annual contract price of ore and the average selling price of HC ferromanganese. This margin is the amount available to cover all production costs, depreciation, interest charges and profits. Clearly the conversion margin for any individual producer may be different because it will be determined by his ore purchase contracts and his own selling prices. However, the trend is a good guide to the health of the industry.

There was a steady recovery in conversion margins in the mid 1990s, as ore prices fell faster than alloy prices, but this trend was reversed in 1997. However, the conversion margin in 1997 was considerably below the levels of 1988-89, even in nominal terms. If inflation is taken into account, the real reduction in conversion margins between 1988 and 1997 was of the order of 40%. This implies a constant need to reduce costs in order to preserve profitability among producers of ferromanganese.

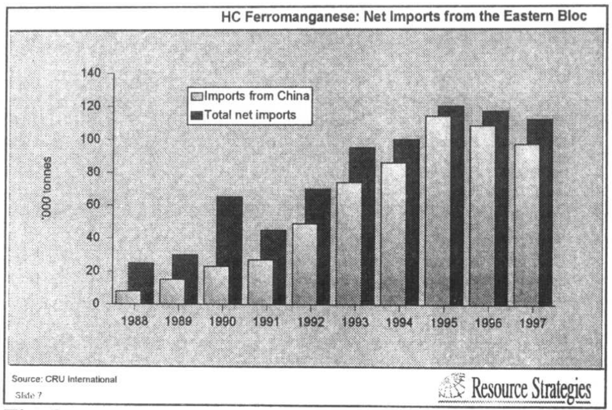

Fig.6.

Pressure on Western producers of ferromanganese has been exacerbated in the 1990s by increasing imports from the Eastern bloc, and principally from China, which have grown to about 120,000 tonnes per year since 1995. This has been driven largely by imports of high grade ore from the West, much which has been converted on a toll basis by Chinese enterprises and re-exported. These imports, however, do appear to have passed their peak.

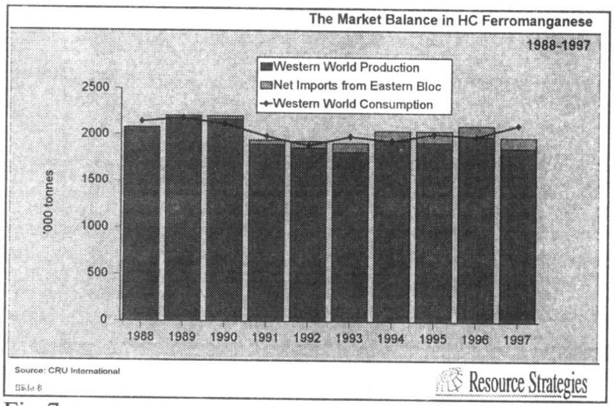

Fig.7.

If we combine the demand and supply figures for high carbon ferromanganese, we find a rather depressing picture for Western producers. There has been no net growth in Western world consumption since 1988; net imports from the Eastern bloc have increased during that period and the production from Western world plants has fallen by about 200,000 tonnes between 1988 and 1997. Ferromanganese producers have therefore had to contend with a falling market for their own production, combined with falling conversion margins.