Developments in Technology for Ferrochromium Production

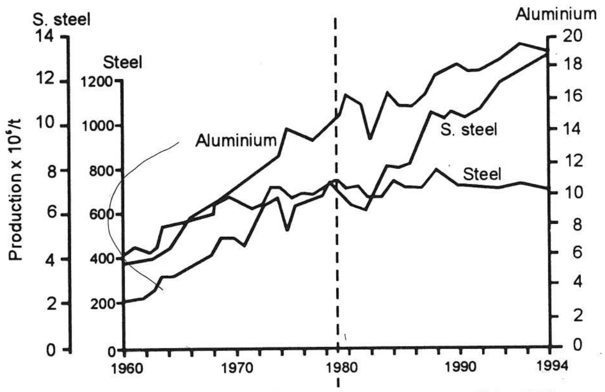
Aidan M Edwards

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



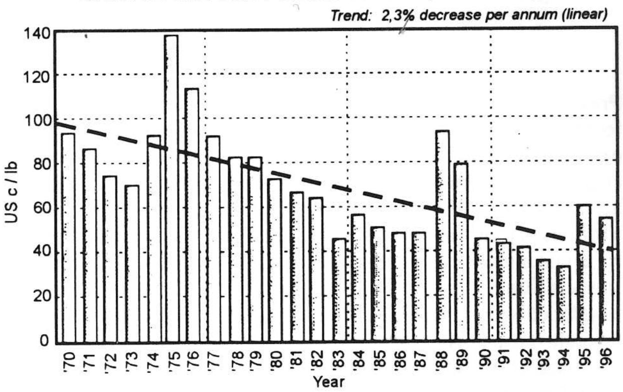
Growth, 1960 - 1974		Growth, 1974 - 1994	
Steel	5,0% p.a.	Steel	zero
S. Steel	8,2% p.a.	S. Steel	4,0% p.a.
Aluminium	8,6% p.a.	Aluminium	2,0% p.a.

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.

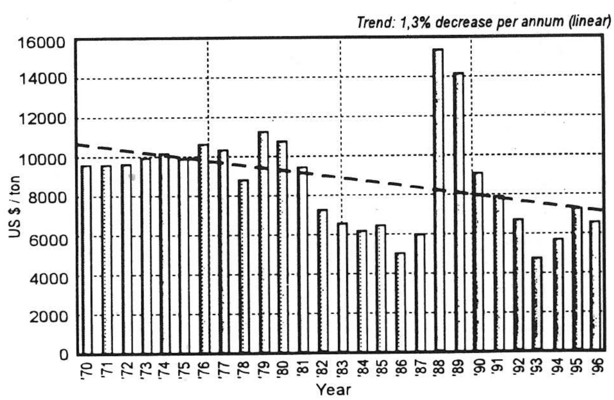
As real prices continue to fall in this highly competitive environment, new technologies must continuously be developed for the industry to remain profitable.

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.

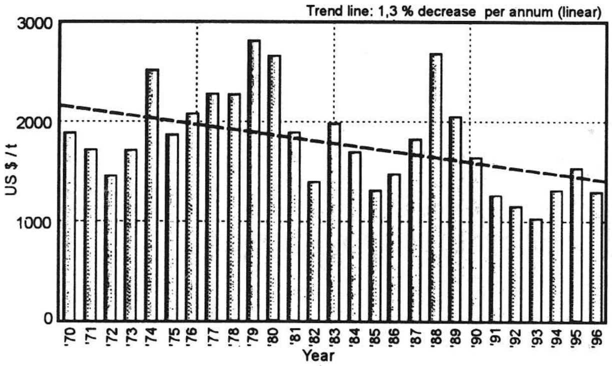
CHARGE CHROME : REAL PRICE - (1990 = 100)



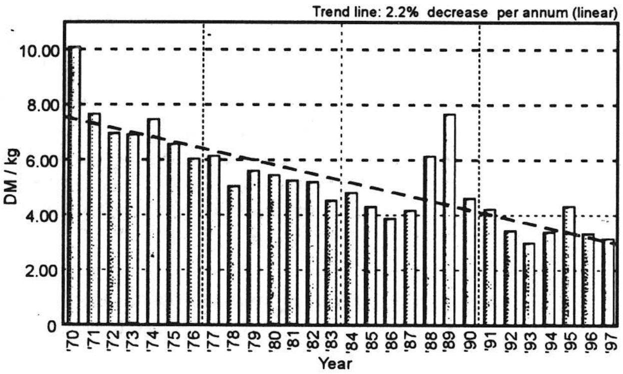
NICKEL REAL PRICE, $ / ton - (1990=100)



ALUMINIUM : REAL PRICE (1990 = 100)

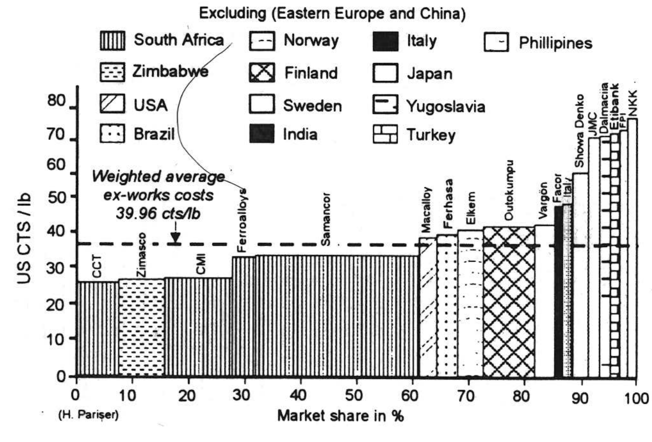


STAINLESS STEEL TYPE - 304: REAL PRICE (1990 = 100)



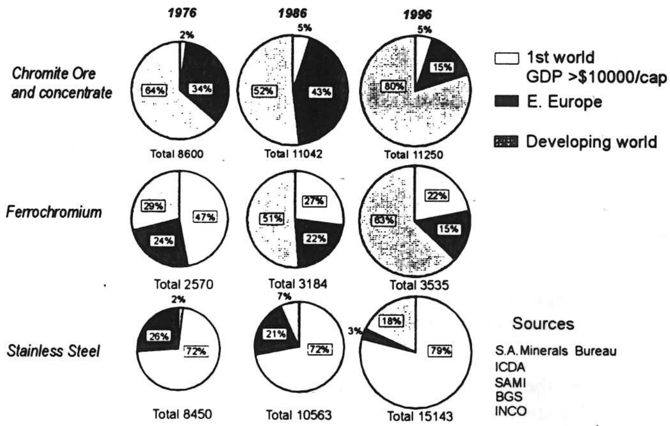
Pressure to remain competitive has resulted in a persistent quest to improve technologies and, at the same time, to relocate operations near the source of the raw material while taking cognizance of the price of the critical ingredient, electrical power, and other forms of energy. Historically, ferrochromium 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%.

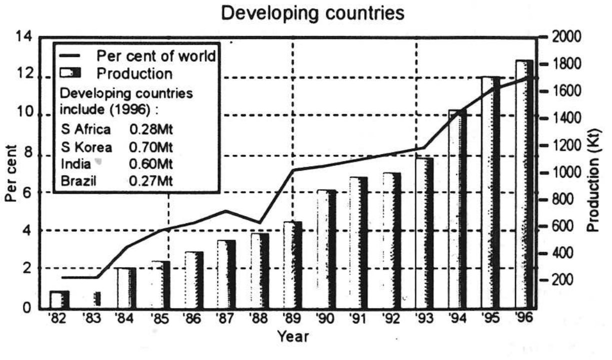
PRODUCTION OF CHROMITE, FERROCHROMIUM AND STAINLESS STEEL (x 10 tons)



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.

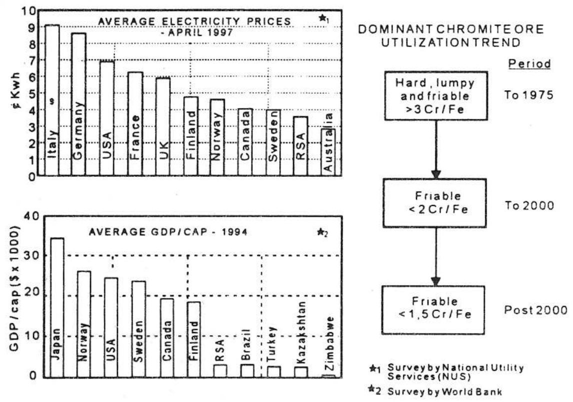
The Minstral furnace controller is another innovative development, which Mintek first introduced to industry at Samancor in 1980. This technology, which allows for effective instrumental control of submerged-arc furnace operations, is now widely used by industry, and already 24 Minstrals are in operation 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.