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A Review of New Ferrochromium Smelting Technologies

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1. INTRODUCTION

The production of ferrochromium in the classical submerged-arc furnace process is almost a century old and continues to dominate the industry. South Africa as a major producer of ferrochromium has continued to investigate and evaluate new process routes in response to the evolving cost structures and market conditions in the industry. Two processes which agglomerate chromite fines and pre-heat⁽¹⁾ or pre-reduce⁽²⁾ them prior to smelting in the submerged-arc furnace have become commercially successful. Only one fundamentally new smelting process however, has achieved this status, namely the d.c. plasma-arc furnace. It is the object of this paper to review the principal types of new smelting processes that have emerged, in order to assess their potential for future implementation and the economic conditions that would favour such developments. The major cost factors for the production of ferrochromium remain energy and raw materials. The submerged-arc furnace as originally developed required lumpy, refractory chromite, high quality coke and utilised only electrical energy. The further development of this process to accommodate less refractory ores, a large proportion of chromite fines (<6mm), and lower cost reductants, such as coals and chars has been remarkable and has significantly lowered the raw material cost. The pre-heating and pre-reduction technologies have also played a major role in lowering the electrical energy requirements for smelting where they have been applied. A number of the new smelting technologies aim to lower the overall energy cost by the replacement of electrical energy with fossil fuel combustion energy. A more detailed comparison of the economic merits of these two energy sources is useful in assessing some of these new processes.

2. ELECTRICAL VERSUS COMBUSTION ENERGY

Electrical energy is essentially neutral with regard to process chemistry while combustion energy yields chemical products such as CO₂ and H₂O which can have a strong effect upon the reducing conditions required to produce ferrochromium. The maximum attainable proportion of the available energy contained in a fuel (the calorific value) which can be utilised in the process (the process energy efficiency) depends upon the outlet gas temperature and oxygen partial pressure. An example of such a calculation for the combustion of pure carbon with air or pure oxygen is given in Figure 1. This shows that to obtain high process energy efficiencies the equipment must be designed to lower the outlet gas CO/CO₂ ratio and temperature as much as possible. These conditions are the exact opposite of those required

for ferrochromium production, wherein lies the challenge to the process engineer. It is however difficult to achieve process energy efficiencies above 50% even with good design.

Electrical energy is capable of achieving efficiencies of 85 to 90% at a reasonable process scale. The use of a process energy efficiency parameter allows a direct energy cost comparison between electrical and combustion energy sources to be made (see for example Figure 2). The use of oxygen enrichment can be readily included in such an analysis and generally is very effective in increasing the process energy efficiency but also constitutes an additional cost over air alone.

The cost of raw materials is simpler in that the friable nature of many chromites creates a need for processes that are able to utilise chromite fines without prior pelletizing or briquetting. Similarly reductant costs can be reduced if the process is able to accept anthracites, bituminous coal or low strength char as fines.

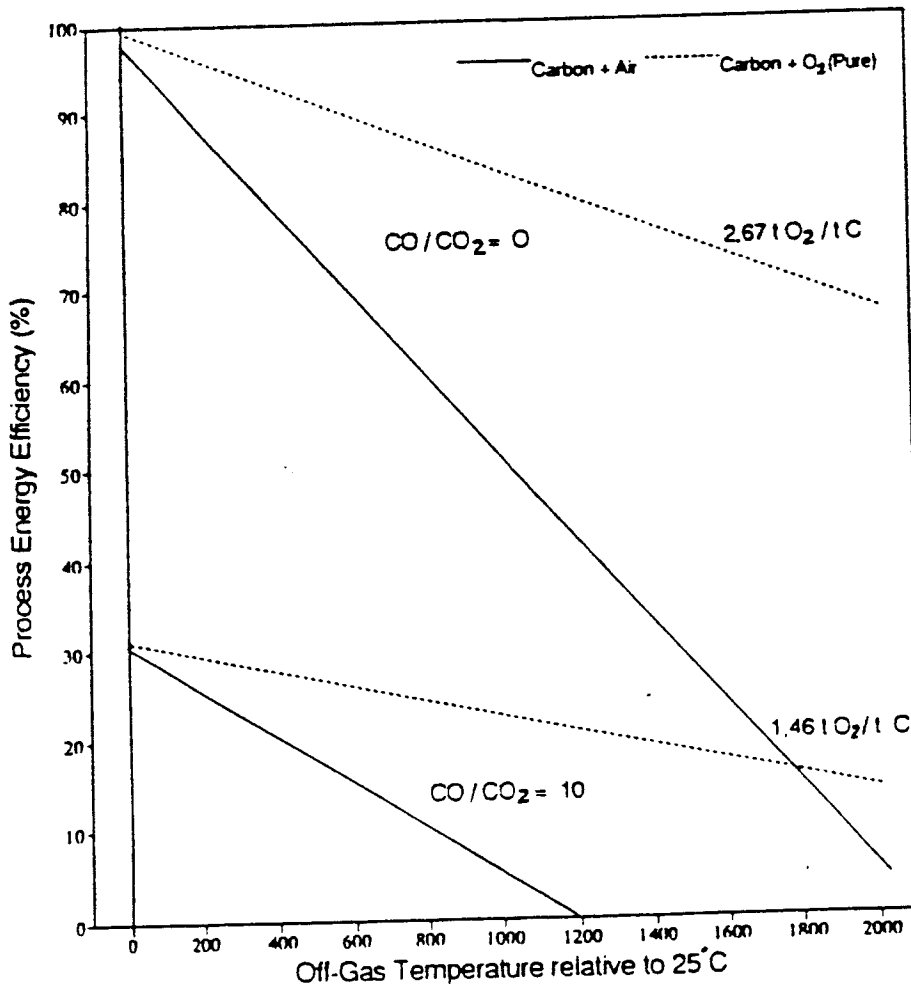


Figure 1: The effects of combustion conditions upon the maximum attainable process energy efficiency

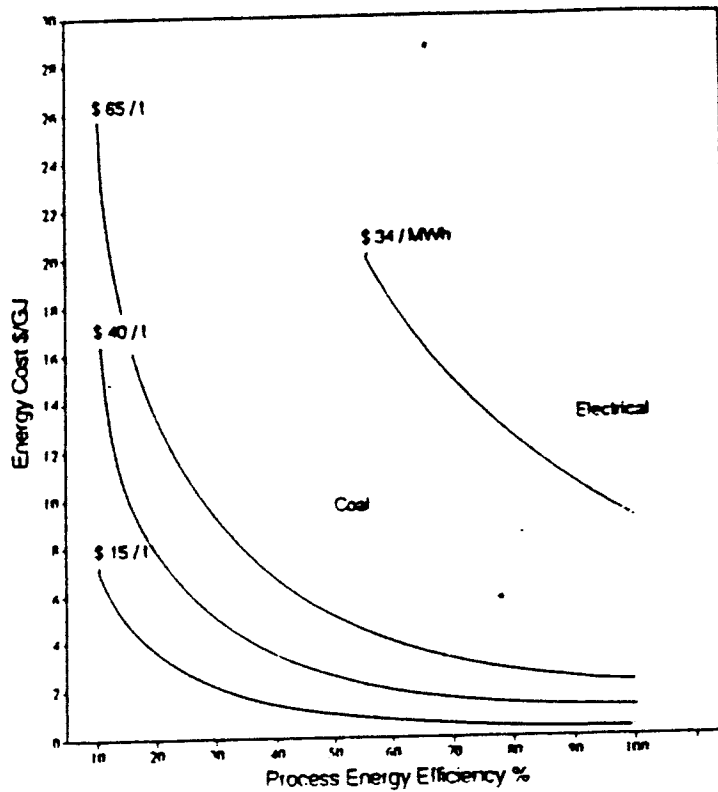


Figure 2: An example of process energy cost comparisons

3. ENERGY COST DRIVEN PROCESSES

Two examples of processes which eliminate electrical energy from the smelting unit have been considered.

3.1 Oxygen Converter Process

This process has been extensively studied and tested at the 30t/day scale by the Research Institute for New Smelting Technologies of Japan⁽³⁾. A schematic flowsheet is shown in Figure 3 in which chromite fines are pre-heated in a rotary kiln and then smelted in a top and bottom blown converter. The process is expected to require 1.17t of petroleum coke and 915m³ of oxygen per ton of ferrochromium (57% Cr). The petroleum coke was required to meet the phosphorous specification of the ferrochromium.

3.2 Shaft Furnace Process

This process⁽⁴⁾ is being developed by Tecnoled. Ltda, Brazil using a novel shaft furnace (see Figure 4) called the FAR furnace. Chromite is incorporated into cold-bonded pellets together with carbon and is pre-reduced in a vertical shaft fired by gas generated in the lower smelting zone. Solid fuel is introduced independently into the smelting zone together with the pre-reduced hot pellets, a hot blast of air and oxygen. Pilot plant tests at 300kg/h of ferrochromium have been carried out and a larger pilot plant furnace has been built to scale up the process.

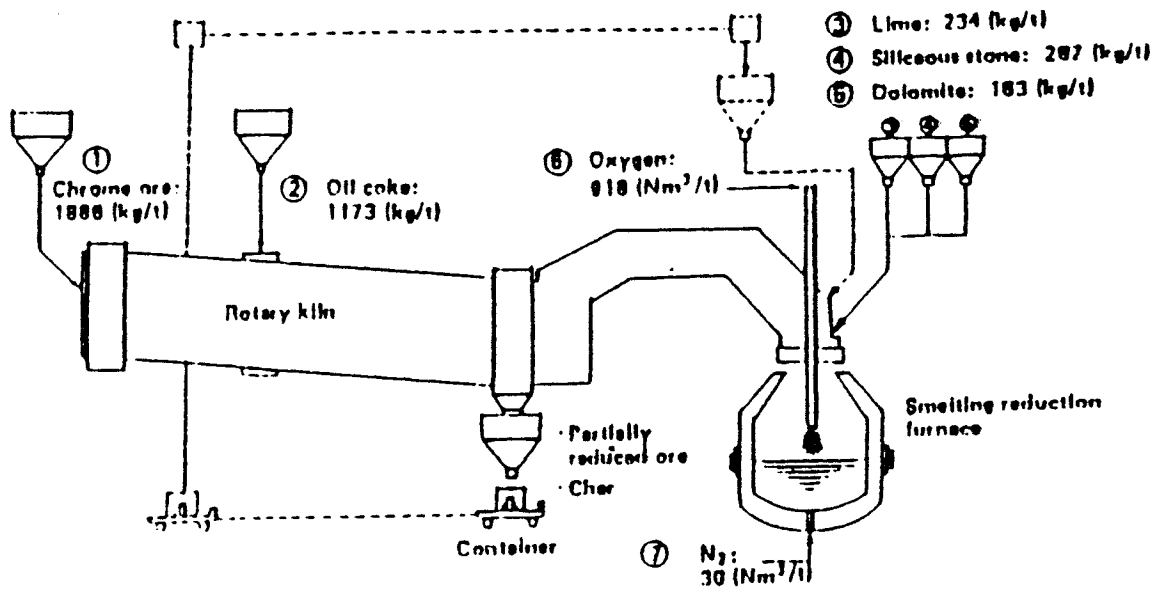


Figure 3: A schematic flow sheet for the oxygen converter process⁽³⁾

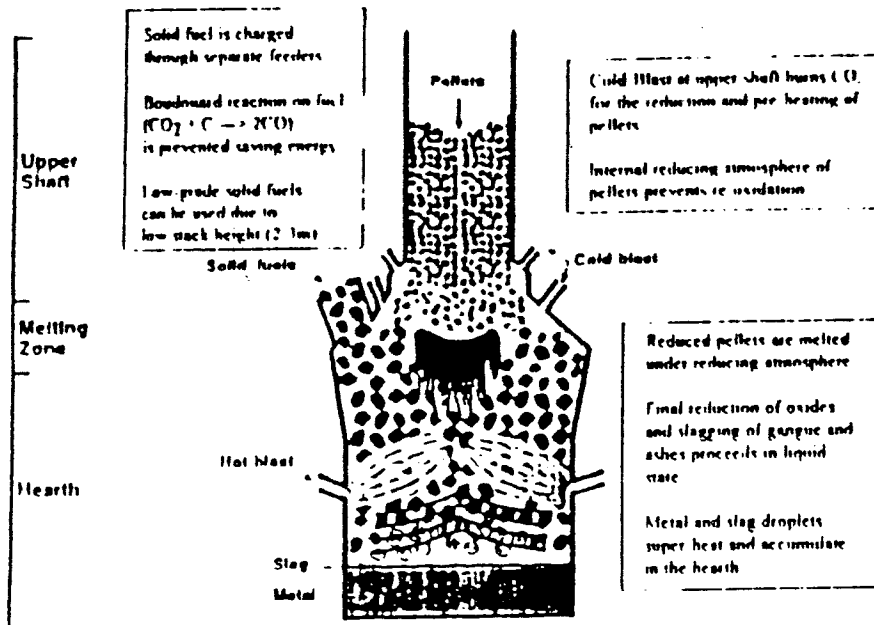


Figure 4: Schematic arrangement of the TECNORED process⁽⁴⁾

4. RAW MATERIAL COST DRIVEN PROCESSES

4.1 Shaft Furnace with Arc Heaters

SKF of Sweden developed the PLASMACHROME process⁽⁵⁾ which was commercialized (5t/h FeCr) but subsequently shut down. SKF developed non-transferred arc gas heaters (see Figure 5) which were used to supply superheated gas into a coke-filled shaft furnace together with finely sized chromite and fluxes (see Figure 6).

The process used 4,94 MWh, 170kg coke and 400kg coal per ton of ferrochromium (54% Cr). The advantages in raw material cost savings on chromite fines appear not to have outweighed the higher electrical energy costs.

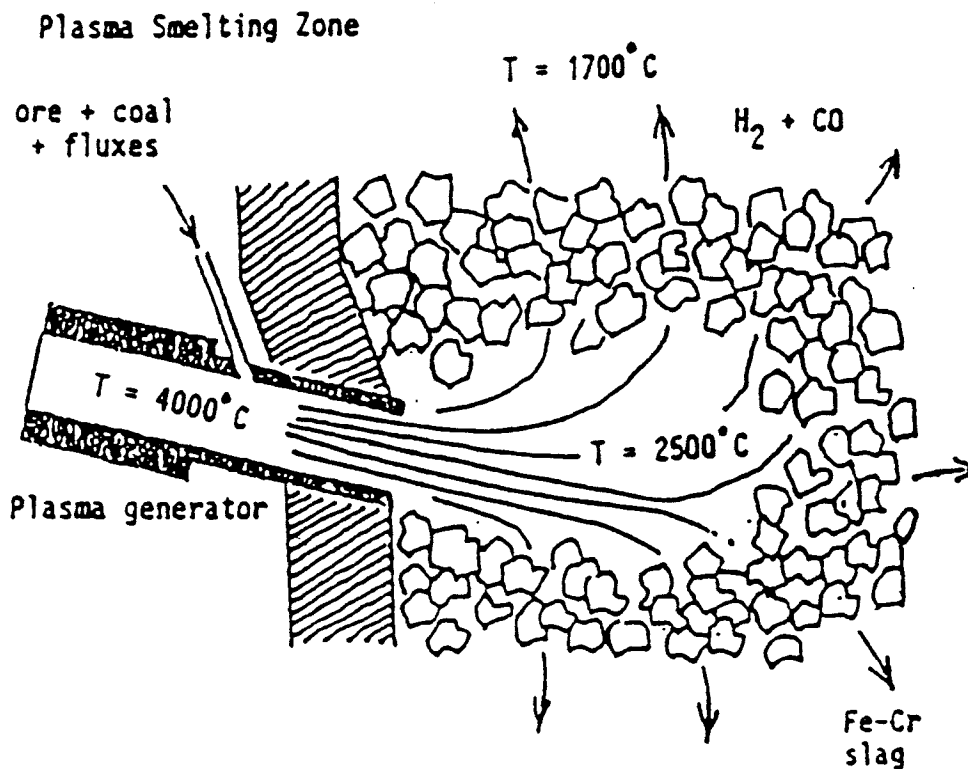


Figure 5: Schematic view of the PLASMACHROME smelting reaction zone ⁽⁵⁾

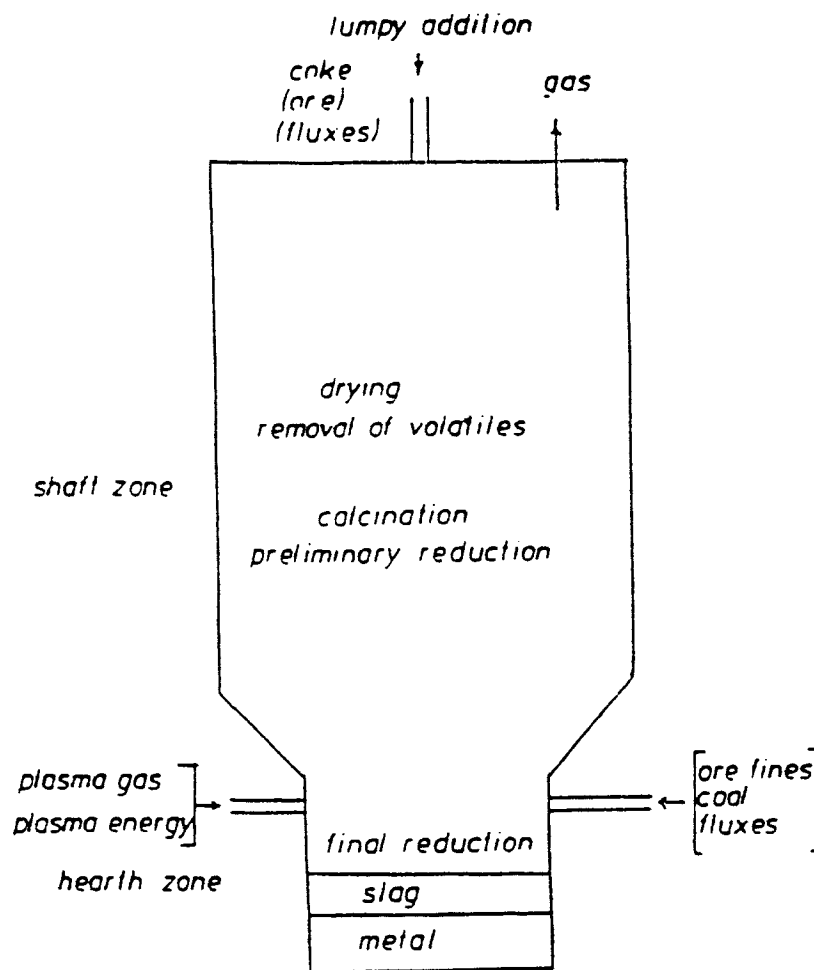


Figure 6: Schematic arrangement of the PLASMACHROME process⁽⁵⁾

4.2 Open-bath d.c. Plasma-Arc Furnace

This process^(6,7) was developed by Mintek and Middelburg Steel & Alloys (now incorporated in SAMANCOR) to treat a 100% less than 6mm chromite and reductant feedstock. A 16 MVA furnace was installed in 1983 and replaced by a 40 MVA unit in 1988 (see Figure 7). A second large unit is to be commissioned this year, treating hot pre-reduced chromite.

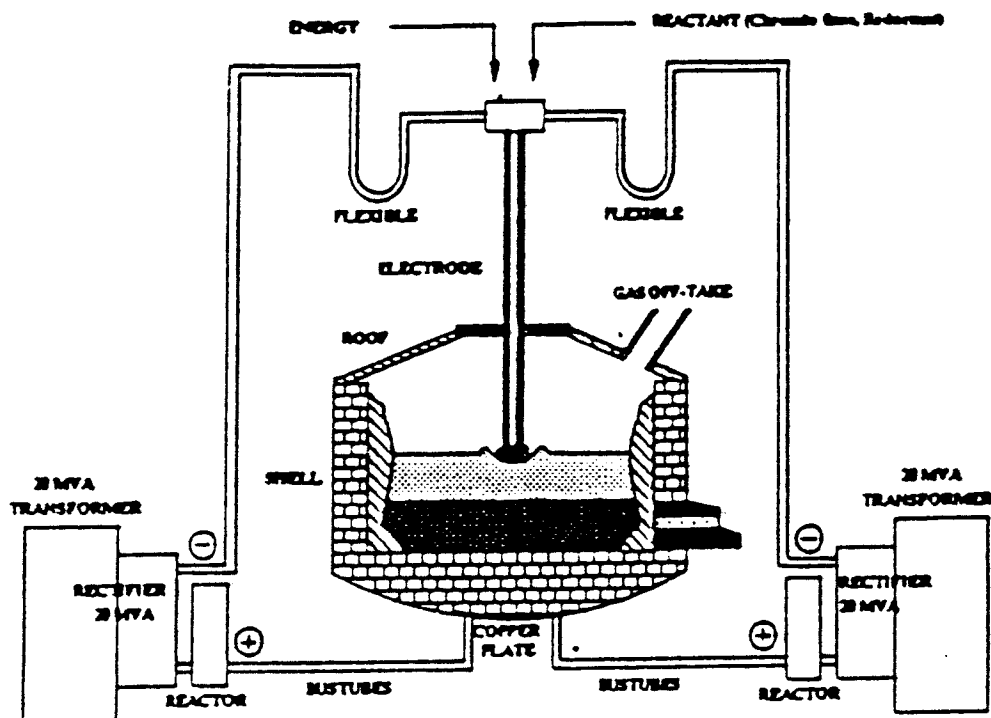


Figure 7: The SAMANCOR 40 MVA d.c. plasma furnace arrangement

5. CONCLUSIONS

5.1 The achievement of a process energy efficiency sufficiently high to compete with current average electricity prices seems not to have been attained for ferrochromium production in an oxygen blown converter. The relatively high consumption of carbonaceous material also creates a phosphorous impurity problem in the product. The combination of large increases in electricity prices and the availability of very low cost, low phosphorous reductant/fuel would be required to commercialize this process.

5.2 The TECNORED process requires further pilot plant development to assess the attainment of good pre-reduction performance in the shaft while keeping the CO/CO₂ ratio in the top-gas low, which will clearly be important to the process economics.

5.3 The PLASMACHROME process would seem to need to lower the electrical energy consumption substantially in order to compete with existing sub-arc furnaces. This is probably due to the large gas flowrates required by the plasma gas heaters and their cooling water heat losses.

5.4 The d.c. plasma-arc furnace has reached the point where it can very effectively compete with conventional submerged-arc furnaces based on the savings achieved via raw material costs.

6. ACKNOWLEDGEMENT

This paper is presented with the kind permission of Mintek.

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