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Operating and Marketing Results of the Production of Intermediate-carbon Ferrochromium in a CLU Converter

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Samancor commissioned a plant for the production of intermediate-carbon charge chrome (IC3) in 1986. Charge chrome is decarburized by bottom blowing with steam and oxygen in a CLU converter. Chromium oxidized during decarburization remains in the converter as a 'dry' slag to be reduced during the next heat by the silicon in the charge chrome. The CLU process has been found to be highly efficient, with chromium recoveries of more than 95 per cent and acceptable converter-lining lives.

The IC3 product has specific attributes that make it advantageous for certain applications. The composition can also be tailored to suit a wide variety of steelmaking applications. IC3 has found its principal applications in the foundry, speciality-steel, and stainless-steel industries, by bridging the previous price and compositional gaps between high- and low-carbon ferrochromium products.

This paper describes the process and operational results achieved during the first four-and-a-half years of production. A detailed description of the product characteristics is given, as well as the place that IC3 has found in the ferrochromium market.

Introduction

Initial efforts to decarburize ferrochromium were mostly confined to the introduction of oxygen through a lance from the top of the converter, and had limited success. The advantages of the bottom blowing of ferro-alloys gained importance as the bottom blowing of steel gained momentum through the Q-BOP process. In one of the earlier tests, blowing was carried out with oxygen and hydrocarbons such as propane or natural gas (the OBM technique). This technique indicated that a carbon grade of less that 1 per cent can be achieved, with a high recovery of chromium[1].

Basson[2] previously reported on the development of a modified CLU process for the production of intermediate-carbon ferrochromium. The present paper describes the actual operational and marketing results achieved by Ferrometals (Samancor) during the first four-and-a-half years of production of intermediate-carbon ferrochromium in a CLU converter.

Operational Results

The process guarantees have all been met and bettered.

(a) Chromium recoveries of over 95 per cent are consistently achieved. This is reflected in the chromium analysis of IC3, which is typically 56,0 per cent.

(b) Converter linings of burnt dolomite have regularly achieved lives in excess of 80 heats.

More than 120 kt of IC3 were produced during the first four-and-a-half years of production.

Product Information

The IC3 product bridges the gap between high- and low-carbon ferrochromium products. Its position in the range of ferrochromium products is shown in Table I. The only other medium-carbon ferrochromium product available in the Western World is a low-carbon ferrochromium that is an off-grade material.

The composition of IC3 can be tailored to suit a wide variety of steelmaking applications. The scope for variation in the chromium and phosphorus contents of IC3 is limited, because charge chrome is used as the input material. Elements that can be varied within wide limits, depending on customer needs, include the following:

(1) carbon, from 1,5 to 5 per cent,

(2) silicon, from 0,2 per cent upwards (IC3 with 1 per cent silicon is produced to yield a granulation product of higher bulk density with a limited amount of small particles),

(3) a higher nitrogen content to suit customers' needs.

The IC3 product has the following specific attributes that make it advantageous for certain applications:

(a) chromium-to-carbon ratios ranging from 10 to 50,

(b) ultra-low titanium values – these values are significantly lower that those of any other ferrochromium product (Table I),

(c) very low silicon values if required,

(d) low sulphur levels,

(e) comparable phosphorus levels.

TABLE I
TYPICAL SPECIFICATIONS FOR FERROCHROMIUM PRODUCTS

Type of alloy	Typical analysis						
	Cr, %	C, %	Cr : C	Si, %	S max, %	P max, %	Ti, %
Charge Cr	50–55	6–8	6–9	2–6	0,05	0,025	0,2–0,5
High-C FeCr	60–70	4–6	10–15	1–3	0,05	0,025	0,1
IC3	54–58	1,5–5	10–50	0,3 max	0,02	0,028	0,01
FeSiCr	35–40	0,06	500	40–42	0,02	0,03	0,2
Low-C FeCr a	58–62	0,015–0,06	>1000	1,0 max	0,02	0,03	0,4
b	68–72	0,015–0,06	>1000	1,5 max	0,02	0,03	0,1

The general specifications of IC3 are given in Table II.

The final product is granulated in a 'Granshot' plant. Because of the metal's toughness, IC3 in granulated form is preferable to IC3 in the conventional lumpy form of material produced via the casting and crushing route. Granulated IC3 falls within the size range 2 to 25 mm, with 75 per cent of the particles being between 5 and 20 mm.

TABLE II
GENERAL SPECIFICATIONS OF IC3

Carbon grade %	Composition, % by mass					
	Cr	Si	Ti	S	P	
1,5	53–58	0,5	0,025	0,025	0,028	R
	55	0,15	0,01	0,013	0,022	T
2,0	53–58	0,5	0,025	0,025	0,028	R
	56	0,15	0,01	0,013	0,022	T
3,0	53–58	0,5	0,025	0,023	0,027	R
	56,5	0,15	0,01	0,01	0,022	T
4,0	53–58	0,5	0,025	0,015	0,026	R
	57,5	0,15	0,01	0,01	0,022	T

R Specification range, maximum level if single figure
T Typical composition
Maximum levels of other elements are: V 0,3; Co 0,07; Ni 0,25; Mn 0,15; Al 0,025; Ca 0,4; Mg 0,1; Zn 0,015; Pb 0,001; Sn 0,01; B 0,005; N_2 0,2; H_2 0,002

The Market for IC3

The world market for medium-carbon ferrochromium is estimated at between 35 and 40 kt/a. Many new applications of IC3, often in relatively small segments, are still being found. The use of IC3 in the production of structural carbon steels is an example. The geographical spread of medium-carbon ferrochromium users is as follows:

Region	Portion of consumption % (approx.)
Europe	32
USA	18
Korea and Taiwan	19
Canada	10
Eastern Europe	7
South Africa	5

IC3 has found its principal applications in the following industries:

Industry	Examples of applications
(a) Foundries	(i) High-chromium white cast iron (2,0%C, 0,4%Si, 32%Cr); IC3 eliminates expensive low-carbon ferrochromium in the induction furnace
	(ii) Chromium, irons (18%Cr, 3,0%C, 0,52%Si); IC3 replaces martensitic stainless-steel scrap; the low silicon content of IC3 is an advantage
(b) Speciality steels	(i) Cor-Ten (Mayari) HSLA steel (0,13%C, 0,46%Cr) BOF tap ladle addition; eliminates expensive Chromsol and ferrosilicochromium
	(ii) Low-carbon strip for galvanizing (0,09%Cr); IC3 is added in the RHOB degasser; eliminates expensive low-carbon ferrochromium
	(iii) Seamless tubing – 52100 grades (1,0%C, 1,25%Cr, 0,005%Ti); EAF tap ladle addition; IC3 is the only product that meets the titanium specification
	(iv) Ball-bearing grades (0,20%C, 0,50%Cr); EAF tap ladle addition; eliminates expensive low-carbon ferrochromium
(c) Stainless steel	(i) Frequently used in VODs
	(ii) Used to shorten process time and increase AOD capacity
	(iii) As a trimming addition to replace expensive low-carbon ferrochromium, where both carbon and chromium are required
(d) Carbon steels	(i) Structural steels ASTM A-588 (0,15%C, 0.50%Cr, 0,3%N, 0,2%Si, 1%Mn).

Figure 1 indicates the relative shares of the above industries.

IC3 has found many specialized applications, as can be seen from the list above. There are many cases where the chemical composition of IC3 is tailor-made for the application. Ball bearings are a typical example – IC3 is the only material available that can meet the ultra-low titanium specification. The low silicon content of IC3 is also often

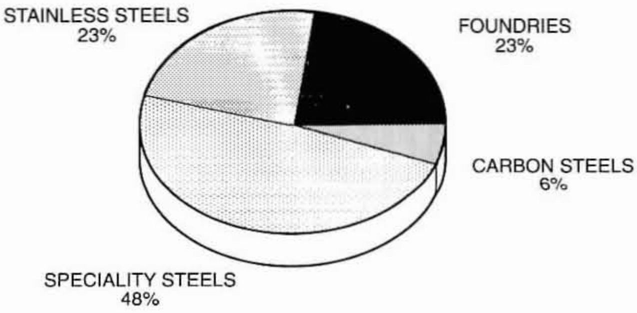

FIGURE 1. Relative size of IC3 market sectors

an advantage where a product has a low silicon specification. IC3 has been a more cost-effective replacement of traditional products in many cases, including low-carbon ferrochromium, ferrosilicochromium, Chromsol, combinations of low- and high-carbon ferrochromium, and stainless-steel scrap (replaced by carbon-steel scrap and IC3).

IC3 should not be regarded as a bulk alloy, but rather as a tailor-made alloy having many specialized applications and meeting the needs of individual customers. There are 85 regular IC3 customers in the world today. This number excludes many small foundries that receive IC3 from foundry distributors. The number of clients is still growing. The number of clients in the USA, for instance, grew from 4 in 1988 to 18 in 1991. The average annual consumption per client is only 350 t.

The –1,5%C and –2,0%C grades of IC3 have proved to be the most popular, with some interest in the –3,0%C grade. The higher-carbon grades compete with high-carbon ferrochromium, but are at a price disadvantage.

The IC3 product, being only in granulated form, has the following advantages:

- easier handling, especially in bulk systems
- no fines and high yield
- fast melting due to a higher iron content.

The bulk density of the granules can be increased, and the fraction of particles smaller than 10 mm decreased, by the granulation of the product with a silicon content of 1 per cent.

Plant Details

The Ferrometals Works of Samancor has a converter plant with a capacity of 50 kt/a in Witbank. Charge chrome is supplied directly from charge-chrome furnaces to the converter, which is in an extension to the crane bay.

The plant consists of the following basic features:

(a) a 25 t CLU converter (Cruesot-Loire-Uddeholm), which is bottom blowing with three tuyères;

(b) a stand-alone, computerized batching and feeding system for raw materials that introduces fluxes and other additions directly into the converter;

(c) a process-gas supply system consisting of a steam-generation plant (operating on carbon monoxide gas produced as a byproduct at the charge-chrome furnaces), with facilities for the supply of mixtures of oxygen, steam, nitrogen, argon, and air to the converter at flowrates of up to 20 Nm^3/min each;

(d) an off-gas extraction and cleaning plant based on conventional wet venturi scrubbing; the flowrate of converter off-gas is approximately 50 Nm^3/min, while the off-gas extraction plant has a capacity of 439 Nm^3/min;

(e) a two-unit Granshot granulation plant; the process works on the principle that a nozzle directs a vertical stream of metal onto a refractory disk, dispersing the metal into a strongly turbulent waterbath, where the metal solidifies into a granular product;

(f) a process computer, which determines the amount of fluxes, ore, and ferrosilicon to be added;

(g) a converter-relining bay, where the two off-line converters can be stripped of their used working linings and relined; relined converters are preheated with carbon monoxide gas, which is a byproduct from the charge-chrome furnaces.

Process Description

The process is cyclic and consists of decarburization and a reduction phase (Figure 2).

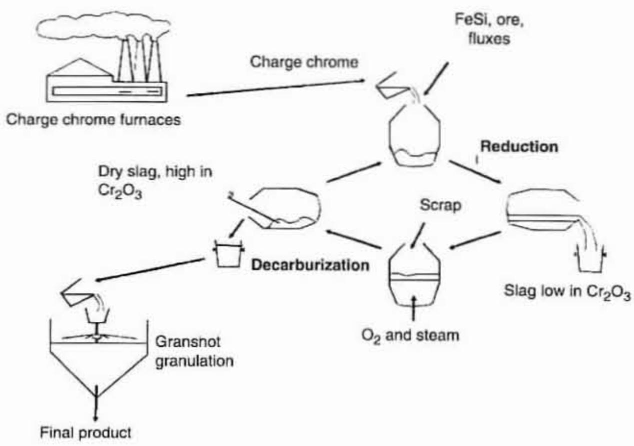

FIGURE 2. Schematic diagram of the IC3 process

Decarburization Phase

The charge chrome is decarburized by the blowing of steam and oxygen through the bottom of the converter, thus oxidizing carbon to carbon monoxide gas. Chromium is, unfortunately, also oxidized in the process. The rate of chromium oxidization increases as the carbon content is lowered. The oxidization reactions are exothermic, and cause a rise in the temperature of the metal bath. There is also an increase in the temperature rise per unit of oxygen blown as the carbon content decreases and more chromium than carbon is oxidized. The temperature is controlled by increasing the steam-to-oxygen ratio and by scrap additions.

The metal is tapped from the converter as soon as the percentage carbon cut-off point is reached, and is granulated. A 'dry' slag, with a high Cr_2O_3 content, remains in the converter. The decarburization rate, when a –1,5% C alloy is produced, is 5 minutes per ton of charge chrome loaded. The decarburization rate is slowed considerably when a carbon concentration of about 2 per cent is reached. Figure 3 shows a typical decarburization profile.

Reduction Phase

Hot charge chrome from the submerged-arc furnaces is transported to the converter in ladles via overhead cranes. The charge chrome and fluxes (burnt lime and dolomite) are added to the dry Cr_2O_3-rich slag from the previous decarburization phase. The silicon in the charge chrome (typically 3 to 7 per cent) is used to reduce the Cr_2O_3 back to chromium metal. The fluxes serve the purpose of keeping the slag at a selected basicity while the silicon in the charge chrome is oxidized to silica.

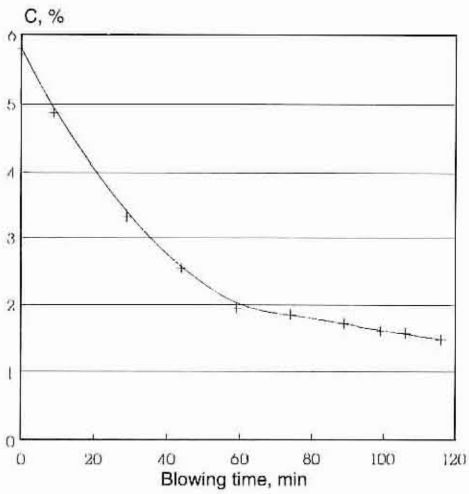

FIGURE 3. Typical decarburization profile

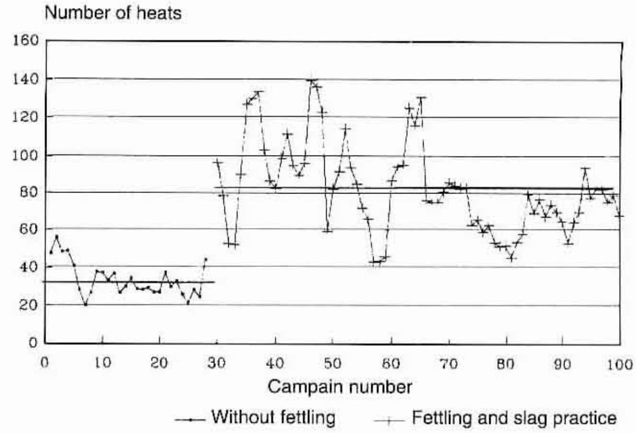

FIGURE 4. Trend in converter-lining life

If the silicon content in the charge chrome is too low to complete the reduction of the Cr_2O_3, ferrosilicon is added. However, should there be an excess of silicon, ore is added to utilize the silicon for the reduction of additional chromium units. The charging of the fluxes, ferrosilicon, and ore is determined by a process computer, and the correct amounts are fed to the converter via a computerized batching system.

The decarburization phase occurs after the reduced slag, low in Cr_2O_3, is tapped off. The time required to complete a whole cycle (reduction and decarburization) is 3 hours when a –1,5%C alloy is being produced.

Converter Refractory Lining

Burnt-dolomite bricks are used on the sidewalls, with either chrome-magnesite or burnt-dolomite bricks on the floor. The converter is built with a 0,9 m floor because of the higher wear rate in the tuyère area.

The initial lining life was low – less than 50 heats per lining for the first 28 campaigns. Subsequent fettling and slag-practice techniques led to a substantial increase in lining life (Figure 4).

Advantages of the CLU Process

The use of steam as a coolant has a number of advantages. It is substantially cheaper than argon (Ferrometals has the advantage of producing steam from furnace off-gas carbon monoxide.) Steam is an effective cooling gas, which enhances temperature control, and thus the lining life.

The process is flexible with regard to the silicon input. If insufficient silicon is supplied from the silicon in the charge chrome, ferrosilicon can be added. If there is an oversupply of silicon from the charge chrome, additional chromium units can be reduced from chromite ore.

The production cost increases as lower-carbon grades are produced owing to a lower chromium recovery as a result of the increased oxidation of chromium. This causes the production of –1%C grades to be uneconomic. However, developmental work on the production of low-carbon grades is continuing.

Conclusion

IC3 has been successful in bridging the previous price and compositional gaps between high- and low-carbon ferrochromium products. It has replaced expensive forms of low-carbon ferrochromium products in certain applications, and is ideal for certain critical applications and speciality steels. The CLU process has proved to be highly efficient. Market indications are that more and more applications are being found, and a growth rate for the product well in excess of that for ferrochromium is projected.

References

1. Franke, H. and Duderstadt, G. (1974). The production of medium-carbon ferrochromium in a bottom-blowing converter and its application to stainless steel. *Proceedings INFACON 74*, pp. 81-84.
2. Basson, J. (1986). The production of intermediate ferrochromium by bottom blowing in a CLU-converter. *Proceedings, INFACON 86*, Supplementary, pp. 147-162.