

COMPLETE SPECIFICATION  
(Section 30(1) - Regulation 28)

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54	Title of invention
	FERROCHROMIUM PRODUCTION.

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FERROCHROMIUM PRODUCTIONFIELD OF THE INVENTION

This invention relates to the production of ferrochromium which preferably has a low carbon content by a process using a chromium containing ore, lime, and ferrochromium silicide for effecting a silicothermic reduction of the chromium and iron oxides.

/BACKGROUND TO

BACKGROUND TO THE INVENTION

One process whereby low carbon ferrochromium is produced is known as the Perrin process. In this process a melt of chromite ore and lime is firstly formed in a conventional a.c. open arc furnace and, subsequently, this melt is intimately mixed in a ladling process with ferrochromium silicide together with additional chromite ore to act as a coolant for absorbing the heat given off by the exothermic silicothermic reduction process. Typically of the order of six re-ladling operations are carried out to effect proper mixing of the melt and ferrochromium silicide and to thereby promote effective reduction.

It is believed that the reason for the two stage process is that the conditions during the formation of the melt of chromium containing ore and lime are accompanied by oxidising conditions whereas the ferrochromium silicide creates highly reducing conditions.

/Repeated re-ladlings

Repeated re-ladlings of the type required in the Perrin process are inconvenient and each re-ladling is accompanied by its own hazards and operating requirements. It would, accordingly, be desirable to minimise such re-ladling operations as much as possible, if not eliminate them entirely.

Added to this difficulty is the fact that certain limestone deposits, when calcined, decrepitate on cooling. The consequence of this is that serious slag boiling in the lime ore melting furnace can occur. It may thus be impractical to use such limestone which, in such an event, would have to be replaced by significantly more expensive calcined limestone often transported over greater distances at accordingly greater cost.

#### OBJECT OF THE INVENTION

It is the object of this invention to provide an alternative process for the production of ferrochromium from chromite ore and limestone whilst still employing the reductive action of

/ferrochromium silicide

ferrochromium silicide to reduce the chromium and iron oxides.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a process for the production of ferrochromium comprising feeding chromite ore and lime together to a furnace bath, and either simultaneously, or sequentially, feeding ferrochromium silicide containing metal to the furnace bath to effect silicothermic reduction of oxides contained in the chromite ore, and withdrawing ferrochromium metal and slag from the furnace.

Further features of the invention provide for the ferrochromium metal and slag withdrawn from the furnace to be mixed together in a ladle prior to final separation thereof into product ferrochromium and slag; for the slag to be contacted with ferrochromium silicide in a ladling step with the resultant ferrochromium silicide containing metal forming that fed to the furnace bath; and for the ladling step to be either a single ladle mixing

/step or

step or a two stage counter current ladle mixing step.

Still further features of the invention provide for the furnace to be a plasma arc furnace, preferably a d.c. plasma arc furnace in which the molten metal bath forms the anode and one or more electrodes in the roof of the furnace form the cathode; for the furnace to be operated at a temperature of from 1400° C to 1750° C and preferably from 1700° C to 1750° C; and for the chromite ore, lime and ferrochromium silicide to be fed directly to the molten bath of the furnace.

It will be understood that reactions which were formerly carried out in two separate stages, namely the furnace and the re-ladling stage into which the ferrochromium silicide reductant was added, is, according to this invention, carried out in a single stage in the furnace. This not only avoids the disadvantage accompanying the multi-stage re-ladling reduction step of the prior art, but also has the advantage of maintaining the exothermic heat generated by the silicothermic

/reduction process

reduction process within the furnace with accompanying energy savings.

In order that the invention may be more fully understood, one embodiment thereof will be described with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing is a schematic flow diagram of a process according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

WITH REFERENCE TO THE DRAWING

At the present time, initial tests have been conducted simply to confirm that the process chemistry can work and that the two steps which were formerly carried out sequentially can be combined in the furnace as provided by this invention. As will be apparent from what follows, further development of the process variables and constraints may be required where higher chromium

/and, or,

and, or, lower carbon contents of the ferrochromium produced are required.

In the tests reported here by way of illustration, the tests were carried out in a 3.2 MVA d.c. plasma arc furnace having an inner diameter of 1240mm, of 460mm depth and having a tap hole flush with the hearth. The base of the furnace had an anode spider plate embodied therein with a plurality of anode conductors extending to the bottom of the hearth so that molten liquid in the hearth actually forms the anode, in use. The furnace had a central electrode extending into the roof of the furnace acting as cathode. In the tests conducted the cathode was a graphite cathode, but where lower carbon contents of ferrochromium are required, this may have to be changed or modified to decrease the amount of carbon transferred from the cathode to the molten metal bath. Another expedient may be to operate with a thicker than normal layer of slag which will prevent, or inhibit carbon from the electrode reaching the metal.

/In each



In each of the two sets of runs described below, chromite or and calcined lime were fed to the plasma arc furnace indicated by numeral (1) on a continuous basis and, in the case of the first run, the temperature was maintained, after reaching steady state, between 1700° C and 1750° C. In the second run, the temperature was somewhat higher at 1750° C to 1800° C on average.

The metal and slag were tapped periodically and simultaneously into a ladle in which re-mixing of the metal and slag occurred once and the slag was thereafter fed from the ladle (2) to a slag washing ladling step (3) in which it was washed with ferrochromium silicide, in the case of the examples given, using a single ladling step. The slag was then considered to be waste and the ferrochromium silicide, now including added chromium extracted by reducing chromium oxides in the initial slag, is fed to the furnace as the reductant for the silicothermic reduction carried out in the furnace.

In each case, feeding of material to the furnace was substantially continuous and intermittent

/tapping took

tapping took place. In the case of the first series of tests, 12 taps were carried out, whilst in the second series described only 8 were carried out. In each case the system had reached steady state towards the last of the taps.

In both cases the composition of the lime was:

Table 1: Average analyses of lime

Analysis of Calcined Limestone (mass%)										
A1203	CaO	Cr2O3	FeO	MgO	MnO	SiO2	TiO2	Fixed C	LOI	TOTAL
1.00	70.14	0.21	11.55	7.12	1.00	3.87	0.05	0.04	2.85	97.83

In the case of the first series of tests the chromite ore had the composition indicated opposite (1) in Table 2 hereunder and the composition of the ferrochromium silicide is similarly indicated in Table 3.

/ Table 2:

Table 2: Average analyses of chromite ore

Analysis of Chromite ore (mass%)										
	Al <sub>2</sub> O <sub>3</sub>	CaO	Cr <sub>2</sub> O <sub>3</sub>	FeO	MgO	MnO	SiO <sub>2</sub>	TiO <sub>2</sub>	Fixed C	TOTAL
1	10.19	0.59	48.78	16.4	16.6	0.018	3.55	0.27	0.017	98.58
2	10.06	1.29	52.01	17.81	14.16	0.19	4.05	0.28	0.016	98.87

Table 3: Average analyses of  
Ferrochromium Silicide

Analysis of FeCrSi (mass%)								
	Cr	Fe	Si	Ti	Mn	C	S	TOTAL
1	37.2	21.3	40.7	0.29	0.31	0.06	0.01	99.87
Analysis of high Chromium FeCrSi (mass%)								
2	41.77	21.16	35.98	0.53	0.44	0.12	0.01	100.01

The ferrochromium metal produced in the first series of tests is shown by tap numbers 8 through 12 in Table 4 below, whilst the results of the second series of tests are shown in Table 5.

/ Table 4:

Table 4: Analysis of metal tapped  
(condition 1, steady state)

Analysis of metal produced during each tap (mass%)									
Tap no	Cr	Fe	Si	Mn	Ti	C	S	P	TOTAL
8	55.50	42.80	1.78	0.22	0.04	0.09	0.01	0.03	100.47
9	55.70	44.60	0.62	0.28	0.04	0.09	0.01	0.02	101.36
10	55.30	40.10	1.12	0.29	0.04	0.11	0.01	0.02	96.99
11	56.50	40.60	0.35	0.31	0.04	0.13	0.01	0.03	97.97
12	58.90	38.70	0.74	0.32	0.04	0.09	0.01	0.02	98.82
Average	56.24	41.44	0.94	0.28	0.04	0.10	0.01	0.02	
Deviation	1.32	2.09	0.50	0.03	0.00	0.02	0.00	0.00	

Table 5: Analysis of slag tapped  
(condition 4, steady state)

Analysis of slag produced during each tap (mass%)											
Tap no	Al2O3	CaO	Cr2O3	FeO	MgO	MnO	SiO2	TiO2	C	TOTAL	Basicity
5	6.41	37.80	8.77	1.71	14.40	0.63	29.50	0.41	0.01	99.64	1.61
6	6.41	37.60	6.74	1.92	14.00	0.59	30.10	0.43	0.01	97.80	1.56
7	6.51	37.70	8.06	2.60	14.50	0.67	32.40	0.45	0.02	102.91	1.46
8	6.37	39.80	6.07	1.54	14.00	0.58	32.90	0.44	0.01	101.71	1.49
Average	6.42	38.22	7.41	1.88	14.21	0.61	31.03	0.43	0.01	100.22	1.54
Deviation	0.05	0.91	1.06	0.40	0.23	0.04	1.45	0.01	0.00	1.96	0.06

It will thus be appreciated that the two reactions can be carried out together in a furnace and that the composition of the product ferrochromium can be adjusted, in the usual way, by adjusting process variables and conditions as well as by suitable choice of starting materials.

/CLAIMS

CLAIMS

1. A process for the production of ferrochromium comprising feeding chromite ore and lime together to a furnace bath, and, either simultaneously, or sequentially, feeding ferrochromium silicide containing metal to the furnace bath to effect silicothermic reduction of oxides contained in the chromite ore, and withdrawing ferrochromium metal and slag from the furnace.
2. A process as claimed in claim 1 in which the ferrochromium metal and slag withdrawn from the furnace are mixed together in a ladle prior to final separation thereof into product ferrochromium and slag.
3. A process as claimed in either of claims 1 or 2 in which the slag is contacted with ferrochromium silicide in a ladling step with the resultant ferrochromium silicide containing metal forming that fed to the furnace bath.
- /4. A process

4. A process as claimed in claim 3 in which the ladling step is a single ladle mixing step.
5. A process as claimed in claim 3 in which the ladling step is a two stage counter-current ladle mixing step.
6. A process as claimed in any one of the preceding claims in which the furnace is a plasma arc furnace.
7. A process as claimed in claim 6 in which the furnace is a d.c. plasma arc furnace in which the molten metal bath forms the anode and one or more electrodes in the roof of the furnace from the cathode.
8. A process as claimed in any one of the preceding claims in which the temperature of the furnace is from 1400° C to 1750° C.
9. A process as claimed in claim 8 in which the temperature is from 1700° C to 1750° C.

/10. A process

10. A process as claimed in any one of the preceding claims in which the chromite ore, lime and ferrochromium silicide are fed directly to the molten bath in the furnace.
  
11. A process substantially as herein described and exemplified.

DATED THIS 5TH DAY OF JANUARY 1996.

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For the Applicant/s



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