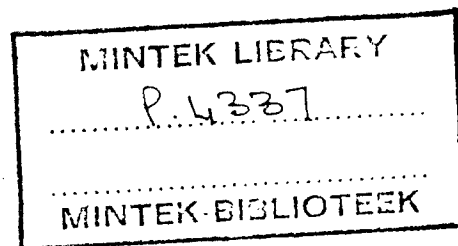


## Complete Specification

(Section 30(1) — Regulation 28)

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51	International classification C22b C01b				
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54	Title of invention "PROCESS FOR THE PRODUCTION OF SILICOMANGANESE AND FERROMANGANESE-SILICON ALLOYS"				



FIELD OF THE INVENTION

THIS INVENTION relates to a process for the production of silicomanganese and ferromanganese-silicon in a pyrometallurgical process.

5 BACKGROUND TO THE INVENTION

Silicomanganese and ferromanganese-silicon are produced in various grades conforming to specified chemical compositions. These alloys contain much less carbon than high carbon  
10 ferromanganese and may be refined to a medium or low carbon ferromanganese by the removal of silicon from the alloy. Such removal is effected in a slagging operation with manganese ore and lime.  
Silicomanganese, apart from being an intermediate on  
15 the path to a low carbon ferromanganese, is also used directly in the steel industry as a deoxidant or alloying agent.

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Silicomanganese (having a silicon content of 12,5% to 21% by mass) is usually made in a submerged arc furnace by a smelting process similar to that used for the production of high carbon ferromanganese. The raw materials are various forms of manganese oxides (ie. manganese ores or manganese slags or both) and quartz together with a suitable carbonaceous reducing agent such as coal or char. The charge for ferromanganese-silicon (having a silicon content of 28% to 32% by mass) generally consists of high carbon ferromanganese and quartz with a suitable carbonaceous reducing agent.

The reaction, as stated, takes place in a submerged arc furnace and silicon monoxide which forms during the reaction disproportionates when it has cooled to about 800°C or less to form silicon and silicondioxide which are retained by the burden.

It is for this reason that it has not been readily possible to produce silicomanganese or ferromanganese-silicon alloys in an open arc furnace as the silicon would be lost as silicon monoxide.

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A possible route would be to smelt high carbon ferromanganese and ferrosilicon or silicon but, in the prior art, it has been stated that this process would be uneconomical in a submerged arc furnace. Thus, V.P. Elyutin in "Production of Ferroalloys" published in Moscow in 1957 at page 128 states "When smelting of 75% or 90% ferrosilicon with carbon ferromanganese, considerable losses of silicon and manganese take place in this case which, combined with a high cost per unit of silicon, characteristic for the 75% or the 90% ferrosilicon make this process uneconomical".

It has, nevertheless, now been found that this is not necessarily true.

#### BRIEF SUMMARY OF THE INVENTION

It is, accordingly, the object of this invention to provide a method for producing silicomanganese and ferromanganese-silicon alloys from ferromanganese and either silicon or ferrosilicon by a pyrometallurgical procedure.

In accordance with this invention there is provided a method of producing molten

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silicomanganese or ferromanganese-silicon alloys comprising the co-melting, in a relatively inert or reducing atmosphere, high or medium carbon ferromanganese and ferrosilicon or silicon or both.

5 Further features of the invention provide for the co-melting to be effected in a plasma furnace, preferably a transferred arc plasma furnace; for the reactants to be added continuously to a bath of molten metal in the furnace at a rate  
10 controlled to maintain the bath in a molten condition and to balance with energy lost and energy required to effect melting of the reactants; for the feed materials to be in the form of "fines" (by  
15 which term is meant particles of less than 6mm in size) and for the molten alloy to be recovered by tapping the furnace bath as and when required.

It will be understood that, in this particular context, the term "plasma" is intended to mean an electrically generated plasma in which the  
20 temperature lies in the range of 5000K and 60000K. The relatively inert atmosphere can be provided by an inert gas such as nitrogen or argon and the exclusion of air can be enhanced by operating the furnace at a slightly positive pressure.

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The furnace can employ either metallic water cooled non-consumable electrodes or consumable electrodes.

5 A significant advantage is that the reaction takes place almost immediately ie. as the reactants become molten and, accordingly, no prolonged heating is required to attain equilibrium conditions.

DETAILED DESCRIPTION WITH REFERENCE TO EXAMPLES

10 In order to demonstrate the operation of the invention, two different series of tests were carried out. The first was a batch melting operation and these tests were carried out in a 100kVA transferred-arc plasma furnace using a hollow  
15 graphite electrode. The electrode was capable of moving axially in order to alter the length of the plasma arc. High alumina and high magnesia crucibles with an inside diameter of 200mm and a height of 400mm were employed. The anodic  
20 connection was established with a steel rod which penetrated centrally through the bottom of the crucible.

The tests were each carried out on 10kgs of material which was fed into the furnace at a controlled rate calculated to maintain the metal bath in a molten state and to balance the energy input with losses and with that required to melt the material.

The materials consisted of high carbon ferromanganese fines (minus 6mm in size) and silicon fines (minus 3mm in size). The compositions of these feed materials are given in Table 1 below.

TABLE 1

FEED MATERIAL ANALYSES, % BY MASS

	Mn	Si	Fe	C	S	P
FeMn fines	73,8	0,83	13,4	6,6	0,014	0,08
Si fines		93,0	1,3	0,2		

Different proportions of the feed materials were employed in the six different runs and the ratios and actual masses are given in Table 2 below. Table 2 also gives the analysis of the silicomanganese produced.

During the melting nitrogen was used as the plasma gas and the average run time was about one hour. The arc power was maintained at about 30kW (600 amp, at 50 volts).

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TABLE 2

BATCH CO-MELTING TESTS.

ANALYSES OF THE PRODUCED SiMn

Run No.	Feed Composition, kg			Analyses of the produced SiMn, % by mass				
	FeMn fines	Si fines	FeMn/Si Ratio	Mn	Fe	Si	C	Total
1.	8,5	1,5	5,7	62,5	17,4	15,2	2,7	97,8
2.	7,3	2,7	2,7	56,4	20,4	20,4	0,9	98,1
3.	8,3	1,7	4,9	52,5	27,6	15,3	2,3	97,7
4.	8	2	4,0	59,3	20,2	15,9	2,2	97,6
5.	7	3	2,3	63,2	13,1	21,5	0,51	98,3
6.	6	4	1,5	56,3	11,6	30,1	0,10	98,1

It will be noted that satisfactory alloys are obtained and the carbon content is substantially decreased relative to that which was contained in the ferromanganese feed material.

A second set of tests in which melting and tapping was carried out was then conducted on a somewhat larger scale but in the same transferred-arc plasma furnace using the same hollow graphite electrode.

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In these tests the furnace had an inside diameter of 370mm and a height of 420mm and was lined with a high magnesia refractory. In this case three steel rods penetrated through the furnace's refractory material.

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In this case the ferromanganese and silicon fines, at the stated ratios given in Table 3, were fed at a constant rate to the furnace. In the case of the first eight batches the total feed per batch was 40kg and in the case of the last four batches was 30kg.

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The furnace was tapped after the melting of each batch. Nitrogen was again used as the plasma gas and the average run time in this case was approximately two hours and the arc power was kept at about 60kW (800 amps, 75 volts). The raw materials were the same, the compositions of which are given in Table 1. The various feed masses and composition of the final alloys are given below in Table 3

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TABLE 3

CO-MELTING CAMPAIGN. MASS AND ANALYSES OF THE PRODUCED SiMn

Melt No	Feed	Composition, kg	
	FeMn	Si fines	FeMn/Si Ratio
1.	34	6	5,7
2.	34	6	5,7
3.	34	6	5,7
4.	34	6	5,7
5.	29	11	2,6
6.	29	11	2,6
7.	29	11	2,6
8.	29	11	2,6
9.	18	12	1,5
10.	18	12	1,5
11.	18	12	1,5
12.	18	12	1,5

Mass (kg), and Analyses (% by mass), of the produced SiMn

Melt No	Mass	Mn	Fe	Si	C	S	P	Total
1.	9,6	58,7	35,6	2,2	3,2	<0,01	0,07	99,8
2.	25,6	67,0	21,3	8,0	3,2	<0,01	0,09	99,8
3.	37,5	60,7	25,8	9,5	2,7	<0,01	0,07	98,8
4.	39,7	62,0	23,0	12,4	2,5	<0,01	0,09	100,0
5.	32,8	59,3	19,2	17,8	1,9	<0,01	0,08	98,3
6.	33,6	60,3	14,9	23,2	0,46	<0,01	0,08	98,5
7.	36,4	59,2	13,2	24,2	1,15	<0,01	0,09	97,8
8.	35,1	60,3	12,9	25,3	0,93	<0,01	0,08	99,5
9.	31,1	55,6	12,1	32,5	0,24	<0,01	0,07	100,5
10.	30,3	50,9	10,4	37,9	0,10	<0,01	0,07	99,4
11.	38,8	55,8	12,7	30,4	0,12	<0,01	0,08	99,1
12.	45,5	54,5	12,6	33,2	0,06	<0,01	0,06	100,4

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The overall mass balances of the feed material are given in Table 4 below

TABLE 4

CO-MELTING CAMPAIGN				Recoveries of metal						
Melting of metal in, kg				Mass of metal out, kg				Recoveries, % by mass		
Total	Mn	Si	Fe	Total	Mn	Si,	Fe	Mn	Si	Fe
440	239,1	110,6	44,9	396	231,9	90,5	65,9	97	82	147*

\*Recovery affected by the presence of a steel heel in the bottom of the furnace at the start of the melting campaign.

It will be noted that in all cases the carbon content of the produced silicomanganese decreased markedly with the increase in silicon content. It was observed after the tests that a thin layer of graphite had formed on the surface of the metal so that the carbon eliminated during the co-melting process must have floated out of the metal following, presumably, an ex-solution process. In this manner a sufficiently low carbon content can be reached to satisfy the chemical requirements of a regular grade of silicomanganese.

Furthermore, a similar ex-solution of carbon has been observed when high carbon

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ferrochromium is co-melted with silicon.

The results also revealed that with this method it is possible to make a low carbon silicomanganese, containing 30% silicon and about 0,1% carbon. The carbon content of the product was, in some instances, even lower than the initial level in the silicon, thus indicating that the conditions for carbon removal in the plasma system are very favourable, that is, kinetically and from an equilibrium point of view. Somewhat lower manganese contents and relatively high iron contents obtained can be attributed to the use of steel anodes and the establishment of a steel heel in the bottom of the furnace at the start of the test runs.

High manganese and silicon recoveries obtained during the melting tests indicate the economic viability of the process.

The invention therefore provides an effective and simple process for the production of silicomanganese and ferromanganese-silicon alloys by the co-melting of high or medium carbon ferromanganese and ferrosilicon or silicon fines which are usually of low commercial value.

WHAT IS CLAIMED IS :-

1. A method of producing molten silicomanganese or ferromanganese-silicon alloys comprising the co-melting, in a relatively inert or reducing atmosphere, high or medium carbon ferromanganese and ferrosilicon or silicon or both.
2. A method according to Claim 1 wherein the co-melting is effected in a plasma furnace.
3. A method according to Claim 2 wherein the plasma furnace is a transferred arc plasma furnace.
4. A method according to any one of the preceding claims wherein the reactants are added continuously to a bath of molten metal in the furnace at a rate controlled to maintain the bath in a molten condition and to balance with energy lost and energy required to effect melting of the reactants.

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5. A method according to any one of the preceding claims wherein the feed materials are in the form of fines as herein defined.

5 6. A method according to any one of the preceding claims wherein the molten alloy is recovered by tapping the furnace both as and when required.

7. A method according to Claim 1 substantially as described in the accompanying description.

10 8. Silicomanganese or ferromanganese-silicon whenever made by a process according to any one of the preceding claims.

DATED this 29th day of NOVEMBER, 1984

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