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PRODUCTION OF CHROMIUM-BEARING ALLOYS

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18 Claims. (Cl. 75—27)

This invention relates to metallurgy and has for an object the provision of improved metallurgical processes and products. A particular object of the invention is to provide improved processes and products employing high-carbon ferrochromium. The invention further contemplates the provision of improved methods of employing high-carbon ferrochromium in the production of chromium-bearing iron and steel products. A further object of the invention is to provide improved exothermic mixtures containing high-carbon ferrochromium and suitable oxidizing material, which mixtures are capable, upon ignition, of reacting within themselves with the development of sufficient heat to melt the iron and chromium of the ferrochromium. A further important object of the invention is to provide reaction mixtures in the form of solid agglomerates comprising particles of high-carbon ferrochromium intimately associated with and bonded together by means of oxidizing material. Products of the invention are covered by claims of my application Serial No. 301,375, filed October 26, 1939, of which this application is a division and which has matured into Patent No. 2,243,783.

The invention contemplates the production and use of reaction mixtures comprising high-carbon ferrochromium and one or more oxidizing agents. The invention provides reaction mixtures containing high-carbon ferrochromium which are capable upon ignition of producing molten ferrochromium products lower in carbon than the ferrochromium employed in the mixtures, a portion of the carbon being oxidized and eliminated by reaction with the oxidizing material. The reaction mixtures may include one or more metals other than iron and chromium, a reducing agent such as silicon (in elemental form or in the form of ferrosilicon or ferrochrome silicon, for example) and one or more reducible metal compounds. The reducing and oxidizing agents (including the carbon of the high-carbon ferrochromium) are provided in such amounts and proportions as to develop sufficient heat to melt any metal present and to reduce the metal of reducible metal compounds present, with the production of molten metal, under the conditions under which the reaction mixtures are employed. According to one phase of the invention, the reducing agents employed consist only or substantially entirely of the non-metallic elements, silicon and carbon. The oxidizing material employed may consist entirely of one or more oxygen-bearing compounds of non-reducible metals (not reducible to the elemental state by the reducing agents employed and under the normal conditions employed in producing chromium-bearing alloys) such as alkali and alkaline earth metals; it may comprise one or more oxygen-bearing compounds of reducible metals such as iron, chromium, nickel, cobalt, vanadium, tungsten, molybdenum, titanium and manganese; or it may comprise one or more oxygen-bearing compounds of non-reducible metals and one or more compounds of reducible metals. The reducible metals may be included in the reaction mixtures as metals (in elemental condition), as silicides or in the form of oxygen-bearing compounds.

The reaction mixtures of the invention are particularly suitable for use in altering the compositions of molten metal baths, as, for example, through incorporation therein of alloying elements like iron, chromium, nickel, copper, cobalt, vanadium, tungsten, molybdenum, titanium and manganese. They may be employed for altering the composition of molten metal when a final product of relatively high-carbon content is to be produced. They may be used with particular advantage in foundry practice for altering the composition of molten iron for casting purposes. They may be used advantageously, also, in producing steel products of various compositions, and they may be employed directly to produce metal products containing various metals in about the proportions in which the metals are present in the mixtures (in the metallic state or as reducible metal compounds or both). When the reaction mixtures are employed for altering the compositions of molten metals they preferably are caused to react on the surfaces of molten baths of the metals.

The reaction mixtures preferably comprise intimately mixed components which are solid at normal atmospheric temperatures. The reducing agents, metals and compounds of reducible metals, preferably are employed in finely divided or comminuted condition, but the metals other than the iron and chromium of the high-carbon ferrochromium may be employed advantageously in the form of metal shot., The oxidizing material employed may be employed in finely divided condition or all or a portion may be employed in the molten state or in the solid state resulting from solidification from the molten state after mixing with the other components. When all or a portion of the oxidizing material is employed in the solid state resulting from solidification from the molten state, it serves as bonding material for bonding together in intimate association the other components of the mixtures.

The solid components of the reaction mixtures which are not solidified from the molten state in forming the mixtures preferably are employed in the form of particles minus 100-mesh in size. Reaction mixtures in which oxidizing material is solidified from the molten state may be formed by mixing all components intimately and thereafter heating the mixtures to temperatures above the fusing temperatures of one or more of the particular oxidizing materials or agents employed. The reaction mixtures may be formed into briquettes or agglomerates of suitable sizes and shapes prior to heating, or the fused, plastic or liquid masses may be cast or otherwise formed into agglomerates of any suitable sizes and shapes in any suitable manner.

When fusion is to be carried out, the oxidizing material should include at least one oxidizing agent having a fusing point below the temperature at which ignition of the mixture, with resulting reaction will take place. Oxidizing agents having suitably low fusing or melting temperatures include many of the oxygen-bearing compounds of alkali metals such, for example, as sodium nitrate, sodium chlorate and sodium dichromate. Other oxidizing agents which may be employed in forming the reaction mixtures include calcium chromate, sodium chromate and manganese dioxide.

According to one important aspect of the invention, high-carbon ferrochromium is employed with suitable oxidizing material to form exothermic mixtures capable of reacting to produce molten ferrochromium containing carbon in lower proportions than in the ferrochromium employed in forming the mixtures. By reaction of the oxidizing agent with the carbon of the ferrochromium (and with the small amount of silicon usually present), all or a large proportion of the heat required for melting the iron and chromium of the ferrochromium is developed or generated. Such reaction mixtures may be caused to react directly on the surfaces of molten metal baths to effect alteration of the compositions of the metals of the baths or they may be caused to react directly, out of contact with molten metals, to produce ferrochromium of altered compositions with respect to carbon.

When the heat developed by reaction of the oxidizing agent with the carbon of the high-carbon ferrochromium is to be relied upon largely or substantially entirely for melting the iron and chromium of the ferrochromium, I prefer to employ ferrochromium containing more than six percent (6%) carbon by weight or even ferrochromium containing about eight to ten percent (8 to 10%) carbon by weight. Ferrochromium containing carbon in the range eight to ten percent by weight, when mixed intimately in finely divided condition with an oxidizing agent such as sodium nitrate or sodium chlorate, reacts rapidly upon ignition to form molten ferrochromium containing less than six percent carbon by weight. The carbon is oxidized preferentially and chromium recoveries readily exceed ninety percent.

In forming reaction mixtures containing high-carbon ferrochromium, I may rely entirely on the heat developed by reaction of the carbon of the ferrochromium with the oxidizing agent or I may incorporate in the mixtures small amounts of silicon which will function to aid in inhibiting oxidation of the chromium as well as in developing heat by reaction with the oxidizing agent. I prefer to employ some silicon in the mixtures when the ferrochromium employed contains less than about eight or nine percent carbon. Also, the presence of silicon is desirable when compounds of reducible metals are present in the mixtures with the ferrochromium and the oxidizing agent, as, for example, when the mixtures contain oxides of metals such as iron, copper and nickel and when the oxidizing materials employed include chromate compounds. The silicon employed may be present in the high-carbon ferrochromium as an alloy component, or it may be added in the form of elemental silicon or in the form of a silicide such as ferrosilicon, low-carbon ferrochrome silicon or a silicide of an alloying element.

The following examples illustrate the production of molten ferrochromium of lowered carbon content by partial oxidation of the carbon of high-carbon ferrochromium, employing sodium chlorate in one case and sodium chlorate in conjunction with oxidized ferrochromium in the other. The oxidized ferrochromium is a product resulting from the oxidation of ferrochromium in the solid state and in the presence of one or more basic compounds such as lime and soda ash under conditions such as to produce a chromate-bearing product. Oxidized ferrochromium may be produced by roasting finely divided high-carbon ferrochromium (preferably minus 100-mesh) with access of air at a temperature above about 1000° C. and below the fusing temperature of the ferrochromium.

The high-carbon ferrochromium used analyzed as follows:

	Percent
Cr	66.4
C	8.2

Sodium chlorate was of commercial grade.

Oxidized ferrochromium was of the following composition:

	Percent
Cr	23.20
Fe	9.45
Cr as Cr_2O_3	15.40
Cr as CrO_2	24.45
Fe_2O_3	13.52
SiO_2	6.55
CaO	35.25
C	.06

Mixing and intimately grinding 100 parts of the high-carbon ferrochromium with 57.6 parts of sodium chlorate, and ignition of the mixture gave a very rapid reaction to fusion, leaving a ferrochromium product containing 63.8% Cr and 6% C.

A mixture containing 100 parts of the high-carbon ferrochromium, 65 parts of the oxidized ferrochromium and 29.6 parts of sodium chlorate reacted immediately to fusion and gave a ferrochromium product containing approximately 62% Cr and 4.8% C.

Oxidized ferrochromium for use in forming reaction mixtures in accordance with the invention may be produced according to any procedure outlined in my United States Patent No. 2,176,688.

The above examples serve to illustrate the reaction involving partial oxidation of carbon in high-carbon ferrochromium to produce a fused ferrochromium of lower carbon content.

When such an exothermic mixture is placed on a bath of molten iron, as, for instance, cast iron, it reacts rapidly to produce molten ferrochromium which enters the molten iron and adds chro-

mium thereto without chilling the iron as when high-carbon ferrochromium is added directly.

The following example illustrates the commercial application of the reaction mixtures:

To add to 1000 pounds of cast iron sufficient chromium to give one percent (1%) chromium in the resulting casting, I add to the molten bath of iron 26.4 pounds of an exothermic mixture comprising 100 parts of high-carbon ferrochromium and 57.6 parts of sodium chlorate ground and intimately mixed (preferably 100-mesh or finer). The reaction is completed in a few minutes. I then remove the small amount of slag and cast the metal as usual. Upwards of 90% recovery usually is made.

Modification of the above procedure can be made with equally good results using, for example, other oxidizing agents, or combinations of oxidizing agents, and slag forming fluxes. A partial or complete oxidation of the loosely held carbon in the high carbon ferrochromium is all that is required to give sufficient heat to melt the iron and chromium of the ferrochromium.

The following examples illustrate the production and use of exothermic mixtures of the invention containing high-carbon ferrochromium, an oxidizing agent and added silicon for aiding in inhibiting oxidation of the chromium and in developing heat for melting the reaction products, the mixtures being employed for altering the composition of molten iron for casting by adding chromium thereto:

The ferrochromium employed contained 66.4 percent chromium and 5 percent carbon.

The silicon was employed in the form of ferrochrome silicon containing 61.5 percent silicon and 21.0 percent chromium.

Example A

An exothermic reaction mixture was formed by grinding together 0.56 pound of the high-carbon ferrochromium, 0.34 pound of sodium nitrate and 0.14 pound of the ferrochrome silicon. The resulting mixture (in which the particles were substantially all minus 100-mesh in size) was heated to a temperature slightly higher than the melting point of the sodium nitrate. The fused mass thus produced was solidified in the form of a briquette which was added to a ladle containing twenty pounds of molten iron. Reaction was initiated immediately and completed in less than one minute. The molten iron before alteration contained

C	Si	Mn	Cr
Percent 3.14	*Percent* 2.30	*Percent* 0.72	*Percent* 0.0

The altered metal product formed analyzed as follows, indicating a chromium recovery of about ninety-two percent (92%):

C	Si	Mn	Cr
Percent 3.17	*Percent* 2.37	*Percent* 0.66	*Percent* 1.84

Example B

In this case the reaction mixture was formed by grinding together 0.575 pound of the high-carbon ferrochromium, 0.236 pound of sodium nitrate and 0.099 pound of the ferrochrome silicon. The mixture was fused and solidified as in Example A and the briquette obtained was added to a ladle containing twenty pounds of molten iron. Reaction again was initiated immediately and completed in less than one minute. The molten iron before alteration contained

C	Si	Mn	Cr
Percent 3.17	*Percent* 2.22	*Percent* 0.73	*Percent* 0.0

The altered metal product formed analyzed as follows, indicating a chromium recovery of about ninety-four percent (94%):

C	Si	Mn	Cr
Percent 3.14	*Percent* 2.28	*Percent* 0.68	*Percent* 1.88

The following examples illustrate the production and use of exothermic mixtures of the invention containing high-carbon ferrochromium, oxidizing agents, metallic alloying agents including copper, nickel and molybdenum and added silicon for aiding in inhibiting oxidation of the chromium and in developing heat for melting the reaction products and the metals present in the mixtures, the mixtures being employed for altering the compositions of molten iron products for casting by adding chromium and the metallic alloying agents thereto:

The ferrochromium employed contained 59.0 percent chromium and 8.2 percent carbon.

The silicon was employed in the form of ferrochrome silicon containing 61.5 percent silicon and 21.0 percent chromium.

Example C

An exothermic mixture was formed by grinding together 0.36 pound of the high-carbon ferrochromium, 0.63 pound of metallic nickel in powder form, 0.06 pound of the ferrochrome silicon and 0.15 pound of sodium nitrate. The resulting mixture (in which the particles were largely minus 100-mesh in size) was fused and solidified as in Example A and the briquette obtained was added to a ladle containing twenty pounds of molten iron. Reaction was initiated immediately and completed in about one-half minute. The molten iron before alteration contained

C	Si	Mn	Cr	Ni
Percent 3.07	*Percent* 2.24	*Percent* 0.74	*Percent* .0	*Percent* 0.0

The altered metal product formed analyzed as follows, indicating a chromium recovery of about 92% and a nickel recovery of about 95%:

C	Si	Mn	Cr	Ni
Percent 3.03	*Percent* 2.15	*Percent* 0.68	*Percent* 0.98	*Percent* 2.74

Example D

An exothermic mixture was formed by grinding together 0.36 pound of the high-carbon ferrochromium, 0.26 pound of metallic copper in powder form, 0.06 pound of the ferrochrome silicon and 0.15 pound of sodium nitrate. The resulting mixture (in which the particles were

largely minus 100-mesh in size) was fused and solidified as in Example A, and the briquette obtained was added to a ladle containing twenty pounds of molten iron. Reaction was initiated immediately and completed in about one-half minute. The molten iron before alteration contained

C	Si	Mn	Cr	Ni
Percent 3.08	*Percent* 2.33	*Percent* 0.72	*Percent* 0.0	*Percent* 0.0

The altered metal product formed analyzed as follows, indicating a chromium recovery of about 90% and a copper recovery of about 98%.

C	Si	Mn	Cr	Ni
Percent 3.10	*Percent* 2.31	*Percent* 0.68	*Percent* 0.94	*Percent* 1.25

When the reaction mixtures are to be employed in loose or powder form, all ingredients or components preferably are incorporated in finely divided forms. When the reaction mixtures are to be formed into fused agglomerates or briquettes, alloying metals incorporated therein may be in the form of relatively coarse particles such, for example, as shot. The fused oxidizing agent thoroughly wets the coarse particles and in its solidified condition serves to hold them within the reaction zone until sufficient heat is developed to melt them. The upper limit of the sizes of any coarse particles employed will depend upon the capacity of the bonding material to retain them within the reaction zone during the course of the reaction.

I claim:

1. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising solid components consisting essentially of (1) high carbon ferrochromium containing silicon and more than about six percent of carbon and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are present in such quantities and are so proportioned that the oxidizing material and the carbon and silicon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

2. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising solid components consisting essentially of (1) high carbon ferrochromium containing more than about six percent of carbon, (2) silicon and (3) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are present in such quantities and are so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

3. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising solid components consisting essentially of (1) high carbon ferrochromium containing more than about six percent of carbon, (2) metallic material other than high carbon ferrochromium, (3) silicon and (4) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are present in such quantities and are so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the metals present in the mixture and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

4. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising solid components consisting essentially of (1) high carbon ferrochromium containing more than about six percent of carbon, (2) one or more metals of the group consisting of nickel, cobalt, copper, vanadium, tungsten, molybdenum, titanium and manganese, (3) silicon and (4) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are present in such quantities and are so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the metals present in the mixture and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

5. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising solid particles of carbon-bearing ferrochromium containing more than about six percent of carbon and solid oxidizing material capable of reacting exothermically with the carbon of the ferrochromium and in which the components are of such compositions and are present in amounts and proportions such as to effect, upon ignition of the reaction mixture, oxidation and elimination of a portion of the carbon of the ferrochromium through reaction of the carbon contained therein with the oxidizing material and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

6. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic reaction mixture comprising (1) solid high-carbon ferrochromium containing more than about six percent of carbon, (2) solid silicon-containing material and (3) solid oxidizing material capable of reacting exothermically with carbon and silicon and in which the compo-

nents are of such compositions and are present in amounts and proportions such as to effect, upon ignition of the reaction mixture, oxidation and elimination of a portion of the carbon of the ferrochromium through reaction of the carbon contained therein with the oxidizing material and carbon is present in the ferrochromium in amount sufficient to produce a substantial exothermic effect by reaction with the oxidizing material.

7. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising particles of high carbon ferrochromium intimately associated with and bonded together by means of oxidizing material solidified from the molten state and capable of reacting with carbon of the ferrochromium with the development of sufficient heat to melt the iron and chromium of the ferrochromium.

8. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) alkali metal nitrate (*b*) alkali metal chlorate and (*c*) alkali metal chromate and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned as to be capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium.

9. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned as to be capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium.

10. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium containing silicon and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned as to be capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium.

11. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium, (2) silicon and (3) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned as to be capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium.

12. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium, (2) metallic material other than high carbon ferrochromium, (3) silicon and (4) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the metals present in the mixture.

13. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium, (2) one or more metals of the group consisting of nickel, cobalt, copper, vanadium, tungsten, molybdenum, titanium and manganese, (3) silicon and (4) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) alkali metal nitrate (*b*) alkali metal chlorate and (*c*) alkali metal chromate and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the metals present in the mixture.

14. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in agglomerated form comprising (1) high carbon ferrochromium, (2) one or more metals of the group consisting of nickel, cobalt, copper, vanadium, tungsten, molybdenum, titanium and manganese, (3) silicon and (4) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are intimately associated with and bonded together by means of the oxidizing material and are present in such quantities and so proportioned that the oxidizing material and the silicon and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the metals present in the mixture.

15. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic mixture consisting essentially of (1) high carbon ferrochromium and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) alkali metal nitrate (*b*) alkali metal chlorate and (*c*) alkali metal chromate and in which the components are present in such quantities and so proportioned that the oxidizing material and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat

to melt the iron and chromium of the ferrochromium.

16. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state an exothermic mixture consisting essentially of (1) high carbon ferrochromium and (2) oxidizing material containing a large proportion of a compound of the group consisting of (*a*) sodium nitrate (*b*) sodium chlorate and (*c*) a chromate of sodium and in which the components are present in such quantities and so proportioned that the oxidizing material and the carbon of the ferrochromium are capable of reacting upon ignition to generate sufficient heat to melt the iron and chromium of the ferrochromium.

17. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture in the form of a solid agglomerate comprising particles of high-carbon ferrochromium, particles of a reducible metal compound and particles of non-carbonaceous reducing material capable of reducing to the metallic state the metal of the reducible metal compound intimately associated with and bonded together by means of oxidizing material solidified from the molten state in contact with said particles.

18. The method of incorporating chromium in iron or steel which comprises igniting in contact with the iron or steel in the molten state a reaction mixture comprising (1) oxidized ferrochromium produced by oxidizing high-carbon ferrochromium and forming an oxidized product low in carbon and containing iron and chromium in oxidized forms, (2) a solid, silicon-containing reducing agent and (3) solid, high-carbon ferrochromium.

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