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METALLURGY

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This invention relates to metallurgy and has for an object the provision of improved metallurgical processes and products. More particularly, the invention contemplates the production and use of reaction mixtures comprising particles of oxidizable material and reducible material in which the reducible material is precipitated on the surfaces of the particles of oxidizable material from solution or by solidification from the molten state. A further important object of the invention is to provide reaction mixtures in the form of solid agglomerates comprising particles of oxidizable material intimately associated with and bonded together by means of reducible material.

This application is a continuation-in-part of my application Serial No. 256,560, filed February 15, 1939.

The invention contemplates the production and use of reaction mixtures comprising (1) reducing agents, (2) oxidizing agents and (3) metals, reducible metal compounds, or metals and reducible metal compounds. The reducing and oxidizing agents 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.

Any suitable reducing agent may be employed in forming an exothermic mixture in accordance with the invention. When carbon is employed as the reducing agent, I may employ carbonaceous material such as coke or I may employ a high-carbon alloy such as high-carbon ferrochromium. (Reaction mixtures comprising high-carbon ferrochromium are described and claimed in my copending application Serial No. 301,375, filed October 26, 1939.) For reasons of economy, when a non-carbonaceous reducing agent is employed, I prefer to employ silicon or a silicide, and, when it is desired to incorporate a particular metal in a metal product produced by reaction, I may employ a silicide of that metal. Thus, for example, when the production of ferrous alloys containing chromium is contemplated, I prefer to employ ferrochrome silicon.

In producing various exothermic reaction mixtures in accordance with the invention, any suitable oxidizing material may be employed. The oxidizing material and the reducing material should be capable of reacting exothermically to produce molten reaction products under the conditions of use of the reaction mixtures. The oxidizing material may comprise a compound, such as sodium nitrate or sodium chlorate, which is free of any metallic element reducible to the elemental state by the reducing agent, or, it may comprise a compound containing a metallic element reducible to the elemental state by the reducing agent such, for example, as sodium chromate, sodium dichromate and calcium chromate.

Precipitation of the oxidizing material on the surfaces of the particles of other components of the reaction mixtures may be accomplished in any suitable manner. Thus, for example, the particles of components other than the oxidizing material may be treated with a solution of the oxidizing material and thereafter dried to remove the solvent, or, the particles of components other than the oxidizing material may be treated with the oxidizing material while molten. In order to accomplish coating by solution and precipitation from solution, a mixture of the oxidizing material with the other components may be moistened with a solvent for the oxidizing material and thereafter dried to effect precipitation of the oxidizing material. The solvent employed may contain, in addition to the oxidizing material an inert bonding substance which aids the oxidizing material in bonding together the other components of a reaction mixture. The components of a reaction mixture other than the oxidizing material may be effectively coated with the oxidizing material while molten by mixing all of the components in the solid state and, thereafter, heating the mixture to a temperature above the fusing temperature of the oxidizing material. When solid agglomerates are to be produced as the result of heating the complete reaction mixture to a temperature above the melting temperature of the oxidizing material, the production of uniform agglomerates may be promoted by moistening the mixture, prior to heating, with a liquid solvent for the oxidizing material. In the case of the preferred oxidizing materials of the invention, an aqueous liquid, such as ordinary tap water or a water solution of some non-injurious material, may be employed satisfactorily. Usually, the use of water in an amount equal to about two to three (2 to 3%) percent of the weight of the reaction mixture is satisfactory and the use of an amount greater than about five (5%) percent of the weight of the reaction mixture is undesirable.

When the components of the reaction mixtures

other than the oxidizing material have been suitably coated with the oxidizing material, the reaction mixtures may be employed as relatively large agglomerates in which the various components are bonded together by the oxidizing material, or, they may be employed as relatively fine powders. Relatively fine powders may be formed by first bonding the various components by means of the oxidizing material and, thereafter crushing or grinding the bonded masses thus produced. Each of the resulting relatively small particles may be of the same composition as the initial bonded masses subjected to crushing or grinding.

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 silicon and alloying elements or metals like copper, nickel, chromium, cobalt, vanadium, tungsten, molybdenum, titanium and manganese alone or in combination with one another or with iron or with iron and one another. 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 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 in contact with molten metals, as, for example, on the surfaces of molten baths of the metals.

Bonding of the components of the reaction mixtures by means of the oxidizing material produces highly desirable intimate mixing of the oxidizing material and the other components by effecting thorough wetting or coating of the other components with the oxidizing agents and provides for more effective reaction upon ignition. When an oxidizing agent is employed in the solid state resulting from solidification from the molten state, or precipitation or crystallization from solution, it serves as a bonding agent for bonding together in intimate association the other components of the mixture.

In forming various reaction mixtures of the invention with silicon as the reducing agent, silicon may be employed as such or in the form of any suitable silicide, such, for example, as a silicide of iron or an alloying element such as chromium. When the silicon is employed in the form of ferrosilicon or ferrochrome silicon, any grade of ferrosilicon or ferrochrome silicon may be employed. The lower limit (percentage) of silicon in the material employed will be determined by practical crushing or grinding considerations and by carbon requirements, and the upper limit will be determined by results sought to be accomplished. Ferrosilicon and ferrochrome silicon products containing less than about fifteen to twenty percent (15 to 20%) of silicon are difficult to crush to suitably small particle sizes. Lower grades of ferrosilicon and ferrochrome silicon contain relatively higher percentages of carbon. Higher grades of ferrosilicon and ferrochrome silicon (containing higher percentages of silicon) may be employed advantageously when silicon is to be incorporated in molten metal baths and when the reaction mixtures to be produced are to contain relatively large burdens of metals, reducible metal compounds and slag-forming materials.

The components of reaction mixtures of the invention may be employed in the form of particles of any suitable sizes. The components, such as silicon-containing material, reducible metal compounds, oxidizing material and fluxing materials, which enter into chemical reactions upon ignition of the reaction mixtures preferably are employed in the form of particles minus 100-mesh in size in order to provide for intimate contact which promotes efficiency in reaction. Components which do not enter in the reactions, such as metals (metallic iron and alloying metals) and silicides which may be provided when increase in the silicon content of molten metal is sought, may be employed in the form of particles of relatively large sizes. The sizes of the particles of non-reacting materials need be limited only by the capacity of the reaction mixture, in the form in which it is employed, to retain the particles within the body of the mixture in the effective reaction zone upon ignition.

When the components are all in the form of relatively small particles (for example, minus 100-mesh) the reaction mixtures may be employed in the form of loose powders or they may be employed in the form of agglomerates in which the particles are bonded together by a bonding agent like sodium silicate or by means of the oxidizing material employed. When the reaction mixtures contain relatively large particles which might settle out of the mixtures if the mixtures should be placed in loose form on the surfaces of molten metal baths, it is desirable to agglomerate the particles and form agglomerates of suitable sizes and shapes which will be capable of retaining the large or coarse particles in the effective reaction zones until molten.

Reaction mixtures of the invention may be agglomerated in any suitable manner as by means of an inert bonding agent such as sodium silicate or by means of an agent such as an oxidizing agent capable of taking part in reactions with other components. I prefer to form agglomerates by employing oxidizing materials capable of functioning as bonding agents for the particles of the mixtures. The oxidizing agents may be employed in finely divided condition or they 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. Bonding by means of the oxidizing agents may be of the type effected through the application of high pressures to quantities of the mixtures; it may be of the type effected through moistening, as with an aqueous liquid, compacting and heating to drive off water; or it may be of the type effected by solidification of the oxidizing agents from the molten state in contact with the other components. Contact of the other components of the reaction mixtures with the oxidizing agents while molten causes effective wetting and coating of the other components with the oxidizing agents and provides for more effective reaction upon ignition. When an oxidizing agent is employed in the solid state resulting from solidification from the molten state, it serves as a bonding agent for bonding together in intimate association the other components of the mixture. In general, oxidizing agents employed should contain oxygen available for reaction with the reducing agent to produce temperatures sufficiently high to result in the production of molten reaction products.

The oxidizing agent employed in forming reaction mixtures when fusion is to be carried out

should be selected to insure a fusing point below the temperatures 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 bichromate. Other oxidizing agents which may be employed in forming the reaction mixtures when incorporation of chromium or manganese in the resulting product is sought, include calcium chromate, sodium chromate and manganese dioxide. Reaction mixtures containing calcium chromate or sodium chromate or both may be agglomerated effectively through the bonding action of the sodium chromate or calcium chromate or both by moistening the mixtures with water, molding agglomerates under pressure and heating the agglomerates to temperatures sufficiently high to drive off free and combined water.

Agglomerates in which the oxidizing material serves as the bonding agent may be produced in any suitable manner. The components which enter into the reactions upon ignition, such as the silicon-containing material and the oxidizing material may be ground together, with or without wetting, to effect intimate mixing, and the resulting mixture may be heated to a temperature sufficiently high to effect fusion of the oxidizing agent without igniting the reaction mixture. Fusion may be carried out in vessels or pans of the sizes and shapes of the agglomerates sought to be produced, in which case the agglomerates may be permitted to cool and solidify in place, or, fusion may be carried out in a master vessel, and the fused mass may be poured into suitable molds for cooling and solidification. Materials, such as metals and any silicides which do not enter into reactions resulting from ignition, may be stirred into the reaction mixtures immediately prior to fusion or after fusion and while the oxidizing material is still molten.

Fused agglomerates of the invention produced by fusing and solidifying the oxidizing materials in contact with the other components provide excellent carriers for materials to be melted by heat developed upon ignition of the mixtures. The agglomerates are very hard and compact and they effectively hold relatively large pieces of metal in the effective reaction zones until they are melted by heat developed in the course of the reactions.

The capacity of the fused agglomerates to retain relatively large pieces or particles of metal in the effective reaction zones makes it possible to employ directly in exothermic mixtures a large proportion of available high-grade scrap metal. The fused agglomerates of the invention also make it possible to employ iron and alloying metals of the types hereinbefore referred to in the form of relatively inexpensive shot instead of in the form of relatively expensive metal powder. Iron and alloying elements of the type identified above may be incorporated in the reaction mixtures in the metallic or elemental state or in the form of reducible compounds, such as oxides, or in both forms.

The exothermic reaction mixtures of the invention preferably are of such compositions as as to be capable upon ignition on the surface of a molten bath of metal such as iron or steel of delivering to the molten metal of the bath molten metal of the types indicated by the compositions of the mixtures. The reaction mixtures may be of such compositions as to be capable, upon ignition in a previously unheated environment, of producing molten metal by means of self-propagating reactions. The heat developing capacity of any reaction mixture produced in accordance with the invention preferably will be determined on the basis of the contemplated use of the reaction mixture. For example, if the reaction mixture is to be placed on the surface of a molten bath of metal, such as iron or steel, at a relatively high temperature and containing excess heat available for melting or for aiding in melting metal present as such in the mixture and any metal which may be produced by reaction upon ignition of the mixture, the components of the reaction mixture may be so selected and proportioned as to provide a relatively low heat developing capacity. If, on the other hand, the reaction mixture is to be placed on the surface of a relatively cold bath of molten metal containing no available excess heat for melting or for aiding in melting metal, or, if the reaction mixture is to be placed on the surface of a bath of molten metal the temperature of which should be increased, or, if the reaction mixture is to be ignited in a previously unheated environment, the components of the reaction mixture may advantageously be so selected and proportioned as to provide a relatively high heat developing capacity in order to melt the metal present as such and any metal which may be produced by reaction upon ignition of the mixture and to establish the molten metal at the desired temperature.

The following examples illustrate the production and use of an exothermic mixture of the invention in the form of solid agglomerates in which reducible metal compounds and a non-carbonaceous reducing agent are bonded together by means of and in intimate contact with an oxidizing agent solidified from the molten state:

An exothermic mixture was prepared by roasting 100 parts of high-carbon ferrochromium (containing 68.5% Cr, 8.1% C and 1.05% Si) with 5 parts of CaO and 2 parts of Na_2CO_3 at 1350° C. to produce oxidized ferrochromium containing approximately .01% C (more or less as desired) and in which the chromium is present substantially entirely in the trivalent condition. The product of oxidation, amounting to about 139 parts, was mixed with 102 parts of ferrochrome silicon (48.5% Si, 30% Cr and .04% C) and 48 parts of sodium nitrate (chlorate, $Na_2Cr_2O_7$ or Na_2CrO_4 may be used) and fused at the melting point of the nitrate and cooled to form a solid mass or agglomerate. The resulting product was an exothermic reaction mixture which, when placed on a bath of molten steel, reacted rapidly to produce molten ferrochromium. Additional lime may be added to the furnace to adjust the lime silica ratio of the slag to any desired degree.

In using this mixture in making steel, for instance, a 12% Cr steel with .10% C, I first melt down approximately 1628 pounds of iron and scrap in a suitable furnace and ore down to reduce the carbon to the desired degree, for example, to about .08%. I then add 760 pounds of the agglomerates to the bath of steel. The reaction is rapid, requiring only a few minutes to go to completion, and there is no chilling of the bath. After the reaction is over the steel is tapped and treated in the usual manner.

The same mixture may be used loose in bags or containers of any suitable design with good

results. The fused briquette with the oxygen carrier however is very compact and confines the reaction to a greater degree to within the mixture itself. Due also to its close contact of particles it reacts faster.

The sodium salt seems to act as a wetting agent, making better contact with the solid particles, helping to propagate the action within the mix, and, thus, speeding up the reaction.

The following examples illustrate the production and use of an exothermic mixture of the invention containing a carbonaceous reducing agent in the form of 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.

The molten iron treated in Example A contained 3.14 percent carbon, 2.30 percent silicon and 0.72 percent manganese, and that treated in Example B contained 3.17 percent carbon, 2.22 percent silicon and 0.73 percent manganese.

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 the molten metal. Reaction was initiated immediately and completed in less than one minute. 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 the molten iron. Reaction again was initiated immediately and completed in less than one minute. 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 example illustrates a reaction mixture of the invention in which carbon functions to react with the oxidizing agent to develop heat and with a reducible metal compound to produce metal:

An exothermic reaction mixture was formed by grinding together iron oxide, carbon and sodium nitrate in the following proportions by weight:

	Pound
Fe_3O_4	1.37
Coke (86% C)	.45
Sodium nitrate	.50

The resulting mixture was moistened with water in an amount equal to about two to three (2 to 3%) percent of the weight of the mixture and formed into briquettes under pressure. The briquettes were heated to a temperature above the melting temperature of sodium nitrate to fuse the sodium nitrate and then cooled to effect solidification. The solid briquettes were placed on the surface of molten iron weighing twenty pounds. Reaction was complete after about four minutes.

Following are analyses of the metal before and after treatment with the reaction mixture:

	T. C.	Si	Mn
Metal before treatment	3.09	2.18	.75
Metal after treatment	3.15	1.62	.52

This type of reaction mixture may be employed for increasing the carbon content and reducing the silicon content of molten metal by the addition of high-carbon, low-silicon molten metal produced by reaction.

I claim:

1. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising a reducing agent intimately associated with and bonded together by means of oxidizing material containing oxygen available for reaction with the reducing agent and capable upon ignition of the agglomerate of reacting exothermically with the reducing agent.

2. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising a reducing agent intimately associated with and bonded together by means of oxidizing material solidified from the molten state containing oxygen available for reaction with the reducing agent and capable upon ignition of the agglomerate of reacting exothermically with the reducing agent.

3. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising one or more non-metallic reducing agents intimately associated with and bonded together by means of an oxygen-containing compound of an alkali metal capable upon ignition of the agglomerate of eacting exothermically with the one or more reducing agents.

4. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising one or more non-metallic reducing agents intimately associated with and bonded together by means of 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.

5. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising silicon intimately associated with and bonded together by means of sodium nitrate.

6. A solid agglomerate suitable for use in met-

allurgical operations containing solid particles comprising carbon intimately associated with and bonded together by means of sodium nitrate.

7. A solid agglomerate for use in the production of molten metal by exothermic reaction comprising (1) solid particles of one or more materials of the group consisting of metal and metal compounds, (2) solid particles of non-metallic reducing material capable of reducing to the metallic state the metal of the metal compound and (3) oxidizing material capable of reacting with the reducing material to generate sufficient heat to melt metal present initially or produced by reduction, said solid particles being intimately associated with and bonded together by means of the oxidizing material.

8. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising metal and non-metallic reducing material intimately associated with and bonded together by means of oxidizing material capable of reacting with the reducing material to generate sufficient heat to melt the metal.

9. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising metal and silicon intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon to generate sufficient heat to melt the metal.

10. A solid agglomerate suitable for use in the production of molten iron by exothermic reaction containing solid particles comprising iron and silicon intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon to generate sufficient heat to melt the metal.

11. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising a metal compound and particles of non-metallic reducing material capable of reducing to the metallic state the metal of the metal compound intimately associated with and bonded together by means of oxidizing material capable of reacting with the reducing material to generate sufficient heat to melt metal produced by reduction of the metal compound, the components of the agglomerate being present in such quantities and being so proportioned that the reducing material is capable upon ignition of the agglomerate of reacting with the metal compound and the oxidizing material to reduce the metal compound to metal and generate sufficient heat to melt the metal thus produced.

12. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising silicon and a metal compound reducible to metal by means of silicon intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon to produce sufficient heat to melt metal produced by reduction of the metal compound, the components of the agglomerate being present in such quantities and being so proportioned that the reducing material is capable upon ignition of the agglomerate of reacting with the metal compound and the oxidizing material to reduce the metal compound to metal and generate sufficient heat to melt the metal thus produced.

13. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising carbon and a metal compound reducible to metal by means of carbon intimately associated with and bonded together by means of oxidizing material capable of reacting with the carbon to produce sufficient heat to melt the metal produced by reduction of the metal compound, the components of the agglomerate being present in such quantities and being so proportioned that the carbon is capable upon ignition of the agglomerate of reacting with the metal compound and the oxidizing material to reduce the metal compound to metal and generate sufficient heat to melt the metal thus produced.

14. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising oxidized ferrochromium and reducing material capable of reducing the iron and the chromium of the oxidized ferrochromium intimately associated with and bonded together by means of oxidixing material capable of reacting with the reducing material to generate sufficient heat to melt metal produced by reduction of the iron and chromium of the oxidized ferrochromium, the components of the agglomerate being present in such quantities and being so proportioned that the reducing material is capable upon ignition of the agglomerate of reacting with the oxidized ferrochromium and the oxidizing material to reduce to metal the iron and chromium of the oxidized ferrochromium and generate sufficient heat to melt the metal thus produced.

15. A solid agglomerate suitable for use in the production of molten metal by exothermic reaction containing solid particles comprising silicon and oxidized ferrochromium intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon to produce sufficient heat to melt metallic iron and metallic chromium produced by reduction of the iron and chromium of the oxidized ferrochromium, the components of the agglomerate being present in such quantities and being so proportioned that the silicon is capable upon ignition of the agglomerate of reacting with the oxidized ferrochromium and the oxidizing material to reduce to metal the iron and chromium of the oxidized ferrochromium and generate sufficient heat to melt the metal thus produced.

16. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising ferrochrome silicon intimately associated with and bonded togther by means of sodium nitrate.

17. A reaction mixture comprising silicon-containing material and one or more metals of the group consisting of iron, chromium, nickel, copper, cobalt, vanadium, tungsten, molybdenum, titanium and manganese intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon of the silicon-containing material to generate sufficient heat to melt the metal present in the mixture.

18. A reaction mixture comprising silicon-containing material and one or more reducible compounds of one or more metals of the group consisting of nickel, copper, cobalt, vanadium, tungsten, molybdenum, titanium and manganese intimately associated with and bonded together by means of oxidizing material capable of reacting with the silicon of the silicon-containing material to generate heat to promote reduction to metal of the one or more metal compounds and to melt the metal produced by reduction.

19. An exothermic reaction mixture consisting essentially of iron oxide, carbon and sodium nitrate in amounts and proportions such that upon ignition of the reaction mixture the carbon will react with the sodium nitrate and iron oxide to generate sufficient heat to promote reduction of the iron of the iron oxide to metallic iron and to melt metallic iron thus produced.

20. A solid agglomerate suitable for use in metallurgical operations containing solid particles comprising one or more reducing agents intimately associated with and bonded together by means of oxidizing material containing a large proportion of calcium chromate.

21. A reaction mixture for use in metallurgical operations involving the production of molten iron and steel comprising particles of silicon-containing reducing material adherently coated with oxidizing material containing oxygen available for reaction with the reducing material and capable upon ignition of the reaction mixture of reacting exothermically with the reducing material.

22. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with oxidizing material by employing water-soluble oxidizing material, wetting a mixture comprising the reducing material and the oxidizing material with an aqueous liquid, and heating the wet mixture to eliminate water.

23. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with the oxidizing material by employing water-soluble oxidizing material, wetting a mixture comprising the reducing material and the oxidizing material with an aqueous liquid, agglomerating the wet mixture under pressure, and heating the agglomerated mixture to eliminate water.

24. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with the oxidizing material by employing water-soluble oxidizing material, wetting a mixture comprising the reducing material and the oxidizing material with an aqueous liquid, agglomerating the wet mixture under pressure, heating the agglomerated mixture to eliminate water and to fuse the oxidizing material, and cooling the mixture to effect solidification of the oxidizing material.

25. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with the oxidizing material by employing water-soluble oxidizing material, wetting a mixture comprising the reducing material and the oxidizing material with an aqueous liquid containing water in an amount equal to about two to five percent (2 to 5%) of the weight of the mixture, agglomerating the wet mixture under pressure, and heating the agglomerated mixture to eliminate water.

26. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with the oxidizing material by employing water-soluble oxidizing material, wetting a mixture comprising the reducing material and the oxidizing material with an aqueous liquid containing water in an amount equal to about two to five percent (2 to 5%) of the weight of the mixture, agglomerating the wet mixture under pressure, heating the agglomerated mixture to eliminate water and to fuse the oxidizing material, and cooling the mixture to effect solidification of the oxidizing material.

27. In a method of producing a reaction mixture for use in metallurgical operations involving intimate mixing of solid particles of reducing material with solid oxidizing material containing oxygen available for exothermic reaction with the reducing material, the improvement which comprises coating the particles of reducing material with the oxidizing material by heating a mixture containing the reducing material and the oxidizing material to a temperature above the melting temperature of the oxidizing material, and cooling the mixture to effect solidification of the oxidizing material.

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