Patented Sept. 5, 1933

1,925,916

UNITED STATES PATENT OFFICE

1,925,916

PROCESS OF PRODUCING ALLOYS

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No Drawing. Application August 15, 1931 Serial No. 557,378

13 Claims. (Cl. 75—8)

This invention relates to alloy iron and steel, especially rustless iron and steel and more particularly to the production of such iron and steel wherein the alloy metal is directly reduced from reducible ores or oxides thereof.

Among the objects of my invention are the production in a simple, reliable and thoroughly practical manner of alloy irons and steels of desired characteristics such as workability, hardenability, corrosion resistance, heat resistance and the like, made to desired specifications of alloying elements such as chromium, chromium-nickel, or the like, which are consistently sound in the ingot and which are especially free from rising or swelling in the mold.

The invention accordingly consists in the several steps and in the relation of each of the same to one or more of the others as described herein and the scope of the application of which is indicated in the following claims.

As conducive to a clearer understanding of certain features of my invention it may at this point be noted that under certain circumstances, in the production of alloy irons and steels, the molten metals, although supposedly well deoxidized, contain excessive quantities of gas in solution. As the metal cools and solidifies, in a mold for example, this gaseous content comes out of the metal causing either a rising or swelling of the metal in the molds, or a decrease in the normal shrinkage of the metal during solidification, with the consequent formation of blow-holes in the solidified metal. These blow-holes render the metal useless for most purposes since the blow-holes introduce fatal flaws in the ultimate product.

This objectionable phenomenon frequently occurs in iron and steel manufacturing processes wherein relatively large percentages of ferro-silicon are employed. Thus, for example, in the manufacture of low carbon high silicon steel for the electrical industries where the silicon content may range from one and one-half per-cent upwards, and in the production of alloy steels of high alloy content this problem becomes of considerable importance. In such irons and steels appreciable quantities of ferro-silicon are employed either as a deoxidizer, an alloying agent, or a reducing agent and in such irons and steels produced in accordance with heretofore known methods there is no assurance of consistently sound metal free from blow-holes and other undesirable effects of gas, a number of which are set forth above.

In heretofore known and/or used processes for the manufacture of ferrous alloys wherein the alloy content is obtained by direct reduction of a reducible oxide of the alloy by means of a suitable reducing agent (for example, in the chromium-iron or chromium-nickel-iron alloys where the chromium content is obtained by a direct reduction of chrome ore in the presence of a molten bath of iron by means of ferro-silicon as a reducing agent) the metal is especially susceptible to the deleterious effects of gas.

Numerous theories have been advanced to account for these effects and various attempts made to overcome them. It has been suggested that this gaseous condition is due to over-oxidation, or to over-reduction, or to casting the metal at too high a temperature. None of these explanations afford any permanent comfort. Heretofore known and/or used processes of the class indicated are not consistently productive of sound gas-free metal.

One of the outstanding objects of this invention is the production of sound, gas-free metal in a simple, practical, economical and thoroughly reliable manner, which metal is consistently free from the many flaws and defects indicated above.

Referring now more particularly to the practice of my invention, in the manufacture of alloy irons and steels the raw materials employed, such as the furnace refractories, raw ores, slag materials or fluxes, oxidizing and reducing agents, and the metallic scrap to a lesser extent, contain varying amounts of moisture, either in a free or combined state or both. Under the intense and prolonged heat of the melting operation, and especially when such operation is conducted in an electric arc furnace wherein the temperature of the electric arc is very intense and electrical conditions promote the dissociation of chemical compounds, this moisture becomes dissociated and forms free hydrogen and oxygen. The oxygen combines readily with any of the oxidizable substances of both slag and metal, leaving the hydrogen free and available for absorption by both slag and metal. Inasmuch as hydrogen is readily soluble in both slag and metal at elevated temperatures, the absorption of hydrogen to a greater or lesser degree is inevitable. This absorption usually takes place into the slag first and then, by means of equilibrium between the slag and metal, is imparted to the metal.

To prevent this gas absorption by the molten allow iron or steel during, for example, the pro-

duction of metal from desired raw materials in a suitable furnace, these raw materials are freed from substantially all normal moisture prior to their being charged into the furnace. Thus the various ores or oxides, the oxidizing and reducing agents, the slag forming or fluxing agents, and, where circumstances warrant it, even the scrap metal forming part of the charge may be dried or freed from substantially all free and combined moisture before these materials are charged into the furnace. Likewise the various refractories employed as furnace lining, especially the hearth or furnace bottom material, are preferably well dried out before the furnace is charged with raw materials.

The necessary pre-drying operation may be accomplished in any desired manner as by heating the raw materials, either mixed or unmixed, in a rotary kiln, or in a hearth or other type of furnace, or by passing these materials through a Dwight-Lloyd or other sintering plant. In furtherance of the drying steps the materials are brought up to and maintained at a desired temperature under conditions fostering moisture removal for a period of time sufficient to remove substantially all normal moisture therefrom. The particular drying temperatures relied upon, as well as the atmospheric conditions under which the drying is carried out and the length of time that the materials are maintained under these conditions are factors which depend upon the nature of the materials to be used.

Thus, scrap metal, where a pre-drying step is considered advisable due to large quantities of dirt, rust, scale or other moisture containing materials being intimately associated therewith, may be brought to a high temperature in an auxiliary drying kiln or furnace of the sort indicated where adequate provision is made for the removal of moisture laden atmosphere therefrom, and is soon rendered moisture free. Likewise the ores or oxides and the slag forming agents, which are the chief sources of contained moisture, may be brought to a fairly high temperature, about 2500° F., for pre-drying these materials and freeing them from substantially all moisture normally contained therein. The reducing agent, however, where the commonly used ferro-silicon is employed, is preferably maintained at a temperature of but about 1000° F. during the drying operation since oxidation of this material, which correspondingly detracts from the reducing character of the agent, readily takes place at higher temperatures.

In general a high drying temperature is preferable in that such a temperature assures removal of a maximum of moisture and requires a shorter drying period.

After the raw materials are properly dried these materials, preferably in a hot, pre-dried condition, are charged into the furnace for further heating in accordance with the particular metal-producing process being carried out. While an immediate transfer of hot, pre-dried materials from dryer to furnace is not essential to a satisfactory practice of my invention, this procedure is preferable since it assures a minimum moisture pick-up by the materials and in addition the incidental pre-heated condition of the materials affords a saving in furnace power, permits a rapid charging of the raw ingredients and allows a highly efficient and rapid procedure throughout.

Where a direct transfer from dryer to furnace is not desired, however, the pre-dried materials may be stored in any convenient place where freedom from moisture absorption or contamination is assured. The dried materials may then be used as desired.

In addition to the elimination of moisture from the raw materials, and thus the effective prevention of moisture dissociation and hydrogen contamination of the metal, a very economical pre-heating of such raw materials is achieved. This results in an appreciable saving in power or fuel costs which are of considerable consequence where an electric arc melting furnace is employed.

When making low carbon steel or iron alloys, especially where the alloy content is derived directly from the ores, a further advantage is achieved in pre-drying the raw materials in that various amounts of carbon contained in coal dust, splints of wood, paper, vegetable matter and the like collected in the raw materials during mining and shipment, are burned during this operation and are thus effectively precluded from contaminating the metal in the furnace. These impurities ordinarily enter the melting furnace alloy with the raw materials where part of the carbon is directly absorbed by the slag and metal and so impart to the metal a higher carbon content than is desired.

As illustrative of the practice of my invention in, for example, the production of a corrosion-resistant chromium alloy iron of about 17% chromium and less than .12% carbon wherein the alloy content is obtained by a direct reduction of the ore, a suitable furnace is first prepared for use.

For example a six ton Heroult electric arc furnace rated three phase, 25 cycle, 1500 KVA, 120 volts is first provided with a suitable furnace hearth lining. This may be made up out of magnesite or chrome brick with a moderate amount of magnesite or chrome ore dust as a filler between the bricks. Both the brick and the filler are very carefully pre-dried before putting the furnace into service. This may be accomplished after lining up the furnace by drying in connection with burning in the bottom. It is preferable, however, especially in connection with the filler, to pre-dry this material before introducing it into the furnace.

A sintered bottom of a desired thickness is then put in by any one of the several standard methods for performing this operation.

The sidewalls and roof of the furnace are next lined with silica brick in accordance with the standard practice. When the furnace has been lined and the hearth sintered into place, illustratively 7500 pounds of ordinary low carbon steel scrap is charged into the furnace. With this metallic charge there is added between 300 and 500 pounds of slag making materials, such as burnt limestone, and about 100 pounds of a suitable oxidizing agent such as iron-ore or mill scale, for bringing the carbon content of the metal to a minimum value.

After the initial charge has been melted down and is brought to a suitable temperature the melt down slag is preferably partially or wholly removed; the amount of slag permitted to remain depending upon the particular requirements of the process.

A mixture of reducible oxide, (illustratively 13,000 pounds of chrome ore analyzing 49% chromium oxide and 15% iron oxide) pre-dried as more particularly described above, and preferably hot, and a reducing agent (illustratively

3,000 pounds 50% ferro-silicon) is then added. The proportions of reducible oxide to reducing agent is preferably such that an approximate 60% excess of reducible oxide is maintained. This total addition for a heat is divided into separate batches, each batch being added as rapidly as possible so as to form a hard, thick crust over the surface of the metal bath. Heating is then continued until this crust of mixed chrome ore and ferro-silicon has fused and reacted chemically to reduce the chrome ore and form a fluid slag; the resulting metals, iron and chromium, gravitating into the underlying metal bath. The resultant slag from which a major portion of the iron and chromium content is recovered is then removed, except for a layer of about one or two inches in thickness which is permitted to remain on the surface of the metal bath.

Where it is found desirable, after the mixture of reducible oxide and reducing agent (illustratively chrome ore and ferro-silicon) has been added and has formed the proper crust over the metal bath, scrap metal of approximately the same analysis as that desired in the tapped metal may then be added. Although scrap of about the same analysis as the tapped metal is desired, good results are achieved, however, where scrap metal of low carbon content and high alloy content is used. The amount of alloy scrap added may be, as desired, from 25% to 50% of the calculated weight of tapped metal.

In adding the scrap metal the total amount of such scrap is preferably divided into batches corresponding to the batches of the reducible oxide and reducing agent described above. These batches of scrap are then charged into the furnace, the batches of scrap alternating with the batches of the mixture of reducible oxide and reducing agent.

When all batches of the reducible oxide—reducing agent mixture and all batches of alloy scrap have been assimilated by the bath of metal the finishing period is commenced; the reducing period being complete when the fluid slag from the last batch of mixed reducible oxide and reducing agent (illustratively, chrome ore and ferro-silicon) has been substantially removed.

At this point, in accordance with standard practice, a lime slag is made which is essentially neutral or even slightly reducing in character, and the metal bath prepared for tapping; the slag forming materials preferably being predried as more fully described above to prevent the introduction of moisture into the furnace.

The heat of metal is then tapped into suitable molds where it solidifies without rising or swelling, the solidified metal being singularly free from the effects of gas. The metal is sound and free of blow-holes and lends itself to forming and processing in accordance with standard practice.

Thus it will be seen that there has been provided in this invention an art in which the various objects hereinbefore noted, together with many thoroughly practical advantages, are successfully achieved. It will be seen that the process is simple, direct and highly efficient and that the metal produced thereby is consistently sound and free from the many undesirable effects of included gases.

While in the illustrative embodiment of my invention neither the initial charge of scrap metal nor the subsequent charge of alloy scrap metal was pre-dried, it will be understood that either or both of these materials may be predried when their moisture content, or the moisture content of impurities intimately associated therewith, is sufficient to warrant such procedure. And likewise, while the reducible oxide and reducing agent are preferably separately predried before mixing them together for charging into the furnace, it will be understood that these materials may be mixed in their raw cold state and then pre-dried as a mixture, care being taken, however, that the pre-drying temperature employed is not so high as to cause partial reaction between the reducible oxide and the reducing agent during this operation.

And while in the illustrative embodiment of my invention the production of sound, gas-free chromium alloy iron is particularly described it will be understood that the production of other alloy irons and steels of a sound, gas-free nature, such as, for example, chromium-nickel alloy irons and steels, may be achieved in a like manner from readily available and inexpensive raw materials including ores and slag-forming ingredients of appreciable free and combined moisture contents.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiment hereinbefore set forth it is to be understood that all matter described herein is to be interpreted as illustrative and not in a limiting sense.

What I claim is:

1. In the production of alloy iron and steel in an electric furnace having a refractory lining, the art which comprises pre-drying said furnace lining, charging said furnace with ferrous metal, and adding to said metal reducible oxides of alloying ingredients from which substantially all free and combined moisture is removed and a reducing agent therefor.

2. In the production of alloy iron and steel in an electric furnace, the art which comprises, charging said furnace with ferrous metal, and adding to said metal chrome ore from which substantially all of the normal moisture content is removed, and a reducing agent therefor.

3. In the production of alloy iron and steel in an electric furnace having a refractory lining, the art which comprises, pre-drying said furnace lining, charging said furnace with ferrous metal, and adding to said metal a pre-dried reducible oxide of an alloy metal, a silicon reducing agent therefor and a slag forming agent from which substantially all free and combined moisture is removed.

4. In the production of high alloy content iron or steel in which the raw materials utilized comprise iron or steel scrap, a slag forming material, a reducible ore of an alloy metal and a reducing agent, wherein said reducible ore is directly reduced by the reducing agent in the presence of a molten bath of iron or steel in an electric furnace, the improvement which comprises predrying at least one of said reducible ore or slag forming materials by heating to a desired temperature under conditions fostering moisture removal for a period of time sufficient to remove substantially all free and combined moisture contained therein before charging said material into said furnace, whereby hydrogen absorption by said bath is minimized.

5. In the production of rustless iron or steel in which the raw materials utilized comprise iron or steel scrap, a slag forming material,

chrome ore and a reducing agent containing silicon, wherein said chrome ore is directly reduced in an electric furnace by the reducing agent in the presence of a molten bath of iron or steel, the improvement which comprises predrying at least one of said chrome ore or slag forming materials by heating to an appropriate temperature under conditions promoting moisture removal for a period of time sufficient to remove substantially all moisture normally contained therein, and charging said material in a hot state into said furnace, whereby hydrogen absorption by said bath is minimized.

6. In the production of rustless irons and steels which includes the step of reducing the oxide of chromium in an electric furnace in the presence of a molten bath of iron or steel, by a reducing agent containing silicon, wherein the raw materials utilized include slag forming materials, and the reducing agent; the improvement which comprises removing from said slag forming materials substantially all the moisture normally contained therein, before introducing said material into said furnace, to maintain the amount of hydrogen absorbed by the bath below the amount which will remain in solution at the solidification point of said iron or steel.

7. In the production of rustless iron or steel having a high chromium content and a low carbon content, in which a chromium oxide is reduced in the presence of a molten bath of iron or steel in an electric furnace by a reducing agent containing silicon, wherein the raw materials include slag forming materials, and the reducing agent, the improvement which comprises removing substantially all of the moisture normally contained in at least one of said raw materials before charging into said furnace, to minimize hydrogen absorption by said bath.

8. In the production of high alloy content irons and steels by means of the direct reduction in an electric furnace of reducible ores of alloy metals by a reducing agent in the presence of a molten bath of iron or steel, the improvement which comprises predrying said ores at a temperature sufficiently high and under conditions fostering moisture removal so as to drive off substantially all moisture normally present in the ores before charging said ores into the furnace, whereby the amount of hydrogen liberated from said moisture and which is absorbed by said bath is maintained below the quantity which will remain in solution at the solidification point of said iron or steel.

9. In the production of rustless iron and steel in an electric furnace, the art which includes, charging the furnace with raw materials for a heat of metal comprising ferrous metal, chrome ore, a reducing agent therefor and slag forming ingredients, said chrome ore and slag forming ingredients having been pre-dried at a high temperature to remove substantially all moisture normally contained therein whereby the introduction of moisture into the furnace is effectively precluded.

10. In the production of alloy iron and steel in an electric furnace, the art which comprises, charging said furnace with ferrous metal to form a ferrous metal bath, heating chrome ore under conditions fostering moisture removal until substantially all of the normal moisture has been removed therefrom, and adding said ore together with a reducing agent therefor to said ferrous bath.

11. In the production of a corrosion resistant iron or steel in an electric arc furnace, the art which includes, preparing a bath of ferrous metal, and adding to said bath a mixture of chrome ore and reducing agent from which mixture substantially all of the free and combined moisture is removed.

12. In the production of a corrosion resistant alloy iron in an electric arc furnace, the art which includes, preparing a bath of ferrous metal; adding to said bath chrome ore from which substantially all of the moisture is removed, ferro-silicon and a hot slag-forming material from which substantially all free and combined moisture is removed, whereby said chrome ore is reduced and the resulting chromium enters the ferrous metal bath.

13. In the production of rustless iron in an electric furnace, the art which includes, preparing a ferrous metal bath; adding to said bath chrome ore and a slag forming ingredient from which substantially all of the moisture has been removed and a reducing agent therefor, whereby said ore is reduced to form a ferrous metal bath containing chromium; and adding to said bath scrap metal of low carbon and high chromium contents.

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