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METHOD OF MANUFACTURING IRON ALLOYS

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This invention relates to metallurgy and more particularly to a method of manufacturing iron alloys of the following metals: Silicon, titanium, zirconium, halfnium, thorium, vanadium, niobium (columbium), chromium and molybdenum. The special purpose of the process is to produce such ferro alloys with any desired given carbon content or to produce them absolutely free of carbon.

In accordance with the invention the process is started with an iron bath which is either free of carbon or contains carbon in any desired quantity. To this bath there is added the carbide of that metal which is to be alloyed with the iron. This carbide-containing iron bath is then, under reduced pressure (in the vacuum), brought to reaction with the oxide of a metal which is also to form a constituent of the finished product. In this connection the metallic constituent of the oxide may be the same as that of the carbide. The oxides and carbides may, however, also contain different metal constituents.

The oxide is advisedly applied to the surface of the iron bath containing the carbide. It can then be stirred into the iron bath by any desired means. In this connection it is advisable to operate in a three-phase (multi-phase) induction furnace described in copending application Serial No. 557,234, filed August 15, 1931, entitled Induction furnaces, issued December 4, 1934, as Patent No. 1,983,242, in connection with which the eddying of the bath and in this way the heating of the bath and the stirring in of the oxide can be effected by the different connection of the individual coils. In the furnace of this said patent the coil arrangement is such that the molten metal is vigorously rotating vertically in a plurality of vertical planes as well as horizontally, thereby recurrently bringing all parts of the bath to the surface and maintaining the metal oxide thoroughly and uniformly distributed throughout the bath. In those cases in which the oxide to be added is sufficiently refractory, the iron can also be melted in a crucible or on a hearth which is made of or lined with the oxide in question.

In general and with most alloys and steels, I prefer to gradually reduce the pressure from atmospheric pressures to about 200 millimeters and to maintain this pressure until the carbon content of the alloy has been reduced to about one per cent. Higher or lower pressures may be employed, if conditions warrant without departing essentially from the present invention. The essential factor involved is to employ a reduced pressure which facilitates the rate of interaction of the carbon of the bath with the added metal oxide, but which controls the rate of evolution of the gas from the metal bath.

During the initial stages of decarburization, the precise pressure employed must be adjusted with respect to the evolution of gas to prevent undue frothing or boiling of the metal bath. With metal oxides that are more difficultly reduced or when the reducing reaction has proceeded nearly to completion it is necessary to use lower pressures than when the metal oxide is more readily reduced or during the initial stages of decarburization. After the carbon content of the alloy has been lowered to below about 0.1 per cent, the pressure may be reduced to 20 to 25 millimeters or lower. This may be readily accomplished by speeding up the rate of evacuating means. It is also preferable to maintain a flow of inert gases under reduced pressure through the furnace, as this serves as a dilutent for the carbon oxide gases evolved from the molten metal bath.

The carbide content of the iron reacts with the added oxide either forming a uniform alloy constituent (if the metallic constituent of the carbide is the same as that of the oxide) or forming two metallic constituents. The metal or metals formed during the reaction, alloy with the iron bath into ferro compounds. Depending on the carbon content contained in the original iron bath and in accordance with the carbon content which is to be contained in the finished product, the added quantity of oxide is chosen in such a manner that it is either exactly chemically equivalent to the total carbon content of the bath or that it exceeds the same somewhat.

The process in accordance with the invention makes it possible, within an exceptionally short time, to alloy a considerable quantity of metals with the iron inasmuch as during the reaction between the carbide and the oxide, metallic alloy constituents are freed from these two compounds which immediately alloy with the iron.

As a specific embodiment of the practice of the present invention in the manufacture of a low carbon titanium iron-alloy I proceed as follows:

I first produce a molten iron bath preferably comprised of low carbon iron and add thereto a quantity of titanium carbide which can be easily obtained by heating a mixture of titanium dioxide with carbon. Titanium dioxide itself is found as the mineral Rutil. In this type of alloy the titanium content is substantially present as a titanium carbide compound. The precise amount of

this titanium carbide that is added may vary widely, depending upon the amount of titanium which is desired in the resultant alloy product. Alternatively, I may add high carbon ferrotitanium made in any convenient manner. Thereafter I add to the molten bath a proportion of a metal oxide compound such as titanium dioxide and vigorously stir the molten metal bath preferably by means of induced electric current until the oxide is thoroughly distributed throughout the molten metal bath. Thereafter the surface of the bath is enclosed and the pressure of the atmosphere over the surface of the bath is reduced gradually from atmospheric pressure to about 200 millimeters of pressure and maintained at this pressure until the rate of evolution of carbon oxides from the bath has become very low. I then reduce the pressure of the atmosphere to a pressure less than 200 millimeters at which within a reasonable short interval of time I may obtain a lowering of the carbon content of the molten bath to the desired per cent. The amount of metal oxide added depends upon the total carbon content of the molten bath and should be in slight excess to that necessary to empirically combine with carbon. As an illustration of the efficiency of the present invention, I may reduce the carbon content of a quantity of 1500 pounds of such an iron-titanium alloy from 7 per cent to 1.0 or 0.8 per cent at pressures approximating 200 millimeters in approximately 90 minutes. To lower the carbon content to below 0.1 per cent, the pressure of the atmosphere must be reduced preferably to between 40 and 30 millimeters for a further period of 60 minutes. Within a further period of 60 minutes at a pressure of about 15 to 20 millimeters the carbon content can be reduced from .1 to .02 or .01 per cent. The removal of this last 0.1 per cent of carbon to 0.01 or 0.02 per cent requires a relatively longer time interval than the removal of carbon down to 1 per cent and the carbon content of the bath may be most easily controlled by regulating the time interval of heating at this lowest pressure. The size of the bath will materially affect the time interval required but with any given volume of molten metal the time interval required with respect to the elimination of carbon per .01 per cent of carbon increases as the carbon content approaches zero. On the other hand the time interval required with respect to the elimination of carbon per .01 per cent of carbon decreases as the pressure over the bath is reduced below 10 millimeters.

What I claim is:

1. The method of forming low carbon iron alloys containing at least one of the elements Si, Ti, Zr, Hf, Th, V, Cb, Ta, Cr, Mo, W, which comprises providing in a furnace a charge consisting of a molten iron bath of relatively low carbon content, converting the charge into carbide-containing iron by adding thereto a determined proportion of a carbide compound of said element, thereafter applying to the surface of the carbide-containing charge at least a substantially equivalent proportion of a carbon reducible metal oxide the metallic constituent of which is desired in said alloy, the said oxide being substantially free of associated slag forming materials, enclosing the surface of the bath from the atmosphere and circulating a gas over the surface of the bath which is substantially inert to the metallic constituents thereof and of said carbide and said oxide, vigorously stirring the said bath while heating the same and circulating the said gases so as to obtain and maintain substantially uniform dispersion of said carbide and said oxide and substantially uniform composition throughout the bath, and continuing the previous operations under gradually diminishing pressures of the gases until the carbon and oxygen content of the bath has been reduced to the desired low percentage.

2. The method of claim 1, the said heating and vigorous stirring of the bath being obtained by induced electric currents adapted to rotate the bath vertically in a plurality of radial planes as well as horizontally, thereby recurrently bringing all parts of the bath in contact with the said gaseous atmosphere.

3. The method of claim 1, in which the molten bath is retained upon a hearth comprised at least in part of a carbon reducible metal oxide and the proportion of oxide added to the bath is reduced accordingly.

4. The method of forming low carbon iron alloys containing at least one of the group of metals including Si, Ti and Zr, which occur in the form of oxides from which carbides can be easily produced which comprises converting the oxide of such a metal into the carbide, providing in a furnace a charge consisting of a molten iron bath of relatively low carbon content, converting the charge into carbon-containing iron by adding thereto a determined proportion of the said carbide, thereafter applying to the surface of said bath at least a substantially equivalent proportion of a carbon reducible metal oxide, the metallic constituents of which is desired in the said alloy, the said oxide being substantially free from slag forming materials, enclosing the surface of said bath from the atmosphere, circulating gases over the surface of said bath which are substantially inert to the metallic constituents of the bath and of said carbide and of said oxide, vigorously stirring the said bath while heating the same and circulating the said gases so as to obtain and maintain substantially uniform dispersion of said carbide and said oxide and substantially uniform composition throughout the bath, and continuing the previous operations under gradually diminishing pressures of the gases until the carbon and oxygen content of the bath has been reduced to the desired low percentage.

5. The method of forming low carbon iron-titanium alloys which comprises forming a molten iron bath of relatively low carbon content, adding thereto a proportion of titanium carbide compound and a substantially equivalent proportion of titanium oxide, the said oxide being substantially free from slag forming materials, enclosing the surface of the bath from the atmosphere, circulating over the surface of the bath an atmosphere substantially inert towards iron and titanium, vigorously stirring the bath while maintaining the same molten to obtain substantially uniform dispersion of the said carbide and oxide throughout the said bath during the circulation of the said atmosphere, and continuing heating and vigorous stirring under gradually reduced pressures of the said atmosphere until the carbon and oxygen content of the bath has been lowered to the desired percentage.

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