May 12, 1936. W. ROHN 2,040,566

VACUUM METHOD OF MANUFACTURING STEEL

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Fig. 1.

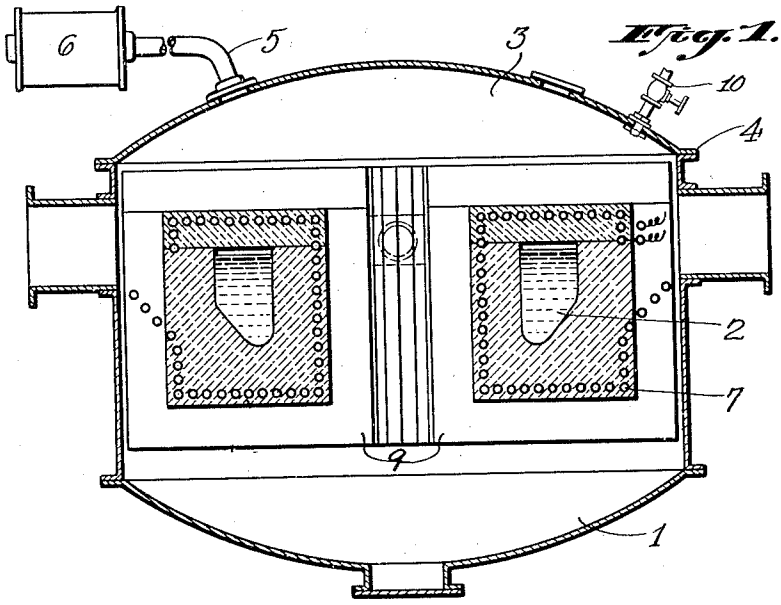
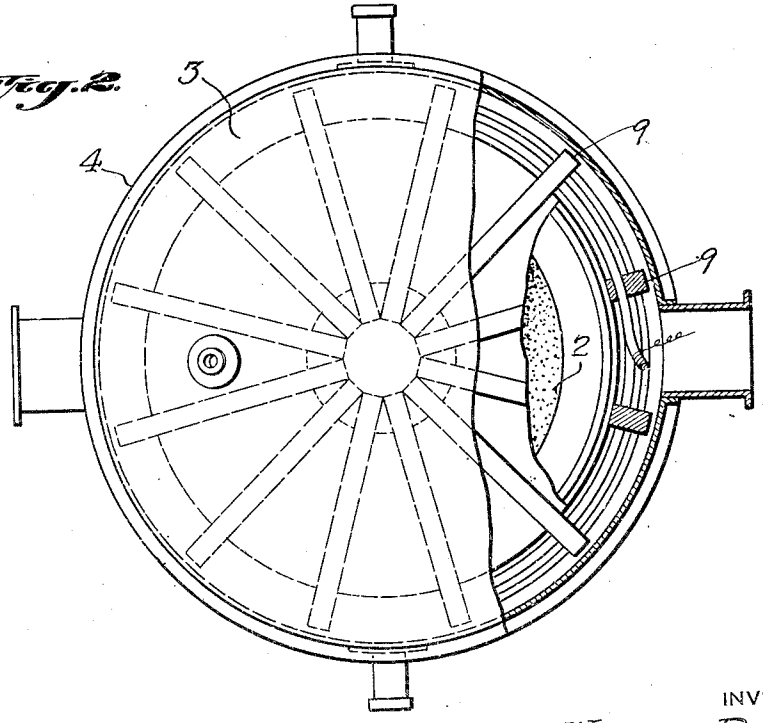


Fig. 2.



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Fig. 3.

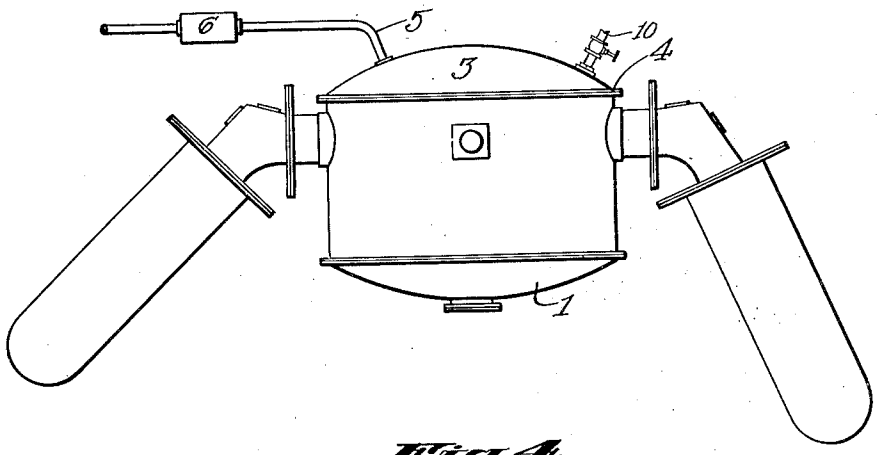
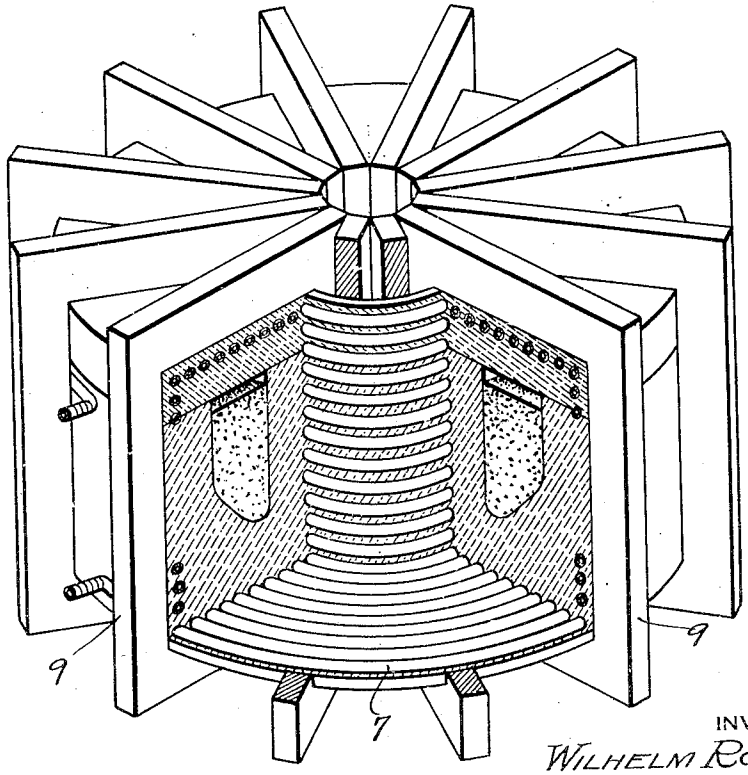


Fig. 4.



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VACUUM METHOD OF MANUFACTURING STEEL

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11 Claims. (Cl. 75—12)

This invention relates to metallurgy and more particularly to methods of manufacturing low carbon iron alloys and steels containing a proportion of one or more of the strong carbide forming elements such as chromium, vanadium, tantalum, manganese, columbium, uranium, titanium and the like whose oxides are difficultly reducible.

One of the objects of the present invention is to provide an improved method for decarburizing such alloys and steels.

Another object of the present invention is to provide a method of decarburizing iron alloys and steels containing one or more of the above identified strong carbide-forming elements without the substantial oxidation of the said element or of the other constituents of the alloy or steel.

Another object of the present invention is to provide an improved method for obtaining low carbon iron and steel alloys containing one or more of the strong carbide-forming elements.

Other objects and advantages will be apparent as the invention is further disclosed.

In accordance with the objects of the present invention, I have found that molten iron or steel alloy baths containing one or more of the strong carbide-forming elements may be successfully and efficiently decarburized without substantial oxidation of the carbide-forming element or of the remaining constituents of the iron or steel alloy, by adding to the bath a proportion of an oxygen-bearing material reducible by carbon and thereafter maintaining the bath molten in an air atmosphere under a maintained reduced pressure, for a time interval sufficient to permit the interaction of the carbon content of the bath with the said oxygen-bearing material and the resultant elimination of the carbon oxide gases from the metal bath into the maintained reduced atmosphere.

One of the features of the present invention is that the amount of oxygen-bearing material added to the molten metal bath need be but in slight excess to that theoretically needed to combine with all of the carbon in the bath.

Another feature of the present invention lies in the maintenance of a reduced pressure of atmospheric gases over the molten bath during the decarburizing reaction. The interaction of the carbon content of the molten metal bath and the carbon reducible oxygen-bearing material added to the bath produces carbon oxides, which are evolved from the metal bath. The rate of evolution of these gases and hence the rate of interaction of the carbon and oxygen-bearing material is dependent upon the pressure of the atmosphere on the surface of the bath and the relative proportion of carbon oxide gases in the said atmosphere.

By reducing the atmospheric pressure and by maintaining the reduced pressure by means of a constantly operating evacuating means, the concentration of carbon oxides in the atmosphere is maintained low in the reduced pressure atmosphere. As a result, a favorable rate of reaction is obtained and the process of decarburization thereby is efficiently and economically facilitated.

In general, the precise low pressure employed may be widely varied without departing from the extent and scope of the present invention. When the carbon content is relatively high in the molten metal bath, very slight reduction in pressures are needed to promote the rapid evolution of carbon oxide gases from the molten metal bath. However, as the carbon content of the molten metal bath decreases, lower pressures are required to effect the removal of carbon oxide gases, until when the carbon content of the metal bath approximates 1.0 percent pressures as low as and lower than 80 to 100 millimeters of mercury and when the carbon content of the metal bath approximates 0.1% pressures as low as and lower than 20 to 25 millimeters of mercury may be employed. The last few hundredths of a percent of carbon are difficult to remove due it is believed to the fact that the extent of dilution of carbon and oxygen-bearing material in the molten metal bath has become so great and that solution pressure limits of carbon and oxygen in the molten metal bath are approached. I have found, however, that while the rate of reaction is materially slowed down with lowering carbon content in the metal bath, by the maintenance of reduced pressures below 20 to 25 millimeters of mercury for prolonged intervals of time, the carbon content of the molten bath may be economically reduced to amounts approximating about .01 percent.

Following decarburization of the molten metal bath, as above described, atmospheric pressure may be restored and the molten metal may be cast in any desired manner. Alternatively, the decarburized metal bath may be degasified by heating in high vacuum, if desired. Vacuum casting of the molten metal bath may be also employed, if desired.

There are many types of furnaces, evacuation pumps, and means for heating the molten metal bath that may be adapted to the practice of the method of the present invention, and such fur-

naces, pumps and means to heat the metal bath do not form a part of the present invention. I prefer, however, to utilize in the practice of the present invention an induction furnace of the general type indicated in the accompanying drawings wherein:

Fig. 1 is a side elevational view of a ring-type inductively heated vacuum furnace; Fig. 2 is a top plan view with the cover removed showing the relative positioning of the parts thereof; Fig. 3 is a second view of the same with means to cast the molten metal in vacuum; and Fig. 4 is a schematic view illustrating the internal structure of the furnace.

As a specific embodiment of the practice of the present invention, the method which has been devised to effect the decarburization of an alloy or steel containing chromium will be disclosed. The alloy or steel is placed in the ring-shaped crucible 2 (Fig. 1) of the furnace 1 (Fig. 1) and a proportion of metal oxide readily reducible by carbon is added thereto. The alloy or steel may be either molten or in solid form, when placed in crucible 2.

Cover 3 is then placed over the furnace and sealed thereto at edges 4 in any convenient manner, and air is exhausted from the furnace through pipe 5 by means of vacuum pump 6.

The metal in crucible 2 is then heated preferably by induced electrical currents from induction means 7 (and cooperating electrical apparatus and circuits not shown), which means includes primary windings 7 and yokes 9 to the temperature at which interaction between the carbon of the metal bath and the added metal oxide is obtained.

This temperature of reaction or the required temperature to bring about the evolution of carbon monoxide from the bath will vary somewhat depending upon bath composition, the specific metal oxide added, the proportion of carbon present in the bath, the specific reduced pressure employed, and the temperature of the bath.

In general and with most types of chromium-containing alloys and steels, I prefer to add as reducible oxidizing material one or more of the following materials; iron oxide, nickel oxide, chrome oxide, or various ores, containing one or more of these oxides. It is preferable when ore materials are used to employ ore concentrates which are substantially free from associated silica or gangue impurities. However, if desired, I may admix with these material one or more of the heretofore well known and so-called "slagging" materials, such as fluorspar for example, which may facilitate the contacting of the oxidizing material with the molten metal bath.

In general and with most chromium-containing 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 percent. 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 reducible oxidizing material, 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 oxidizing materials 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 oxidizing material is more readily reduced or during the initial stages of decarburization. After the carbon content of the alloy has been reduced to below about 0.1 percent, the pressure may be reduced to 20 to 25 millimeters or lower. This may be readily accomplished by speeding up the rate of evacuating gases. It is preferable to maintain a flow of atmospheric gases under reduced pressure through the furnace, as this serves as a dilutent for the carbon oxide gases evolved from the molten metal bath. Such circulation of atmospheric gases through the furnace may be obtained in any convenient manner as by operation of vacuum means 6 while regulating valved opening 10 in cover 3 permitting the entrance of atmospheric gases to the cover 3.

As an example of the practice of the present invention, a 600 pound charge of high-carbon ferro-chrome (carbon approximately 5%, chromium approximately 60%) may be decarburized in accordance with the present invention by heating to temperatures approximating 1750–1850° C., adding thereto chromium oxide in amounts in slight excess to that theoretically computed to combine with the carbon, reducing the pressure gradually to about 50 millimeters until the carbon content of the alloy approximates 0.1%, then reducing gradually to about 10–20 millimeters and maintaining at this 10–20 millimeters until carbon content approximates .01 percent. The rate of decarburization may vary within wide limits depending upon the conditions existing. In one experiment, the carbon content was reduced from about .28 percent to.06 percent in about 2 hours running time. After one and one half hours running time, the carbon content was reduced from .06 to about .01 percent. If the resultant dilution of the chromium is not deleterious, other oxygen-carrying materials such as iron oxides, mill scale, nickel oxide and the like may be employed instead of chromium oxide.

As a result of the practice of the present invention, the product obtained is a low carbon ferro-chrome substantially free from metal oxides by a simple, economical refining or decarburizing process applied to high carbon ferro-chromium. Heretofore in the art, this has been difficult to obtain. This low-carbon ferro-chromium may be added to a low carbon steel or to a low carbon nickel-iron alloy in the forming of low carbon chrome steel or low carbon iron-nickel-chromium alloys. (Chromium steel and nickel chromium steel may be treated by the same method.)

The product from the decarburizing process, if it be a low-carbon ferro-chrome, may be cast at atmospheric pressure in the customary manner, or where the product is a low-carbon steel which is desired substantially gas-free, the heating may be continued for a time interval under high vacuo and then cast either at atmospheric pressures or in vacuo. To cast the alloy in vacuo, the cover 3 may be provided with two oppositely positioned water-cooled ingot molds 15 into which the molten metal may be poured directly from the crucible 2 by tilting the furnace in the proper direction.

As a further step, if desired, after degasification in high vacuum, the molten metal may be allowed to solidify in situ in the crucible, thereby expelling the gases held in solution at the temperature of heating. Thereafter on reheating to fusion in vacuo the expelled gases are effectively elimi-

nated and the thus vacuum cast metal is of lower gas content than that obtained without solidification and remelting. If desired, the solidification and remelting may be repeated.

In general, however, and for most purposes chromium-containing iron and steel alloys decarburized in accordance with the present invention do not require a pressure lower than about 20 to 25 millimeters to effect decarburization down to a few hundredths of a percent carbon and substantial degasification of the decarburized metal is obtained at these pressures. This decarburized alloy may then be cast at atmospheric pressures in externally positioned molds with good results. It is only where special uses or special properties are desired in the alloy that high vacuum treatment and casting and solidification in vacuo is required. The ordinary residual gas content of a decarburized alloy may be generally taken care of by slight additions of heretofore employed degasifying elements such as titanium, zirconium, aluminum and the like.

It is therefore apparent from the above description and drawings of the present invention that many modifications and departures may be made therein without departing from the nature and scope thereof and that whereas as a specific embodiment I have described the same as it has been applied to ferro-chromium I am not to be limited thereto as the process is applicable with only slight modification to all ferro-alloys of the strong carbide forming elements defined and to steel alloys containing said elements. All such modifications and departures are contemplated as may fall within the scope of the following claims.

What I claim is:

1. The method of decarburizing iron and steel alloys containing at least one of the strong carbide-forming elements, chromium, titanium, uranium and the like which comprises heating the said steel to temperatures above the melting point, adding thereto a carbon-reducible oxidizing material, enclosing the molten steel bath from the atmosphere, circulating atmospheric gases over the surface of the bath and continuing the heating of the bath under gradually reducing pressures of said atmospheric gases until the carbon content of the bath has been lowered to the desired minimum.

2. The method of claim 1, in which the molten bath is heated by induced electrical currents adapted to vigorously stir the bath while heating the same to maintain the said carbon-reducible material uniformly dispersed throughout the said bath.

3. The method of claim 1, in which the pressure of said atmospheric gases is gradually reduced from atmospheric pressures to approximately 20 to 25 millimeters of mercury as the carbon content of said bath reduces to amounts approximating 0.1 per cent.

4. The method of claim 1, in which the bath is maintained at a temperature favorable to the reduction of said carbon-reducible oxidizing material by the carbon of the molten metal bath.

5. The method of claim 1, in which the amount of carbon-reducible material added is proportioned with respect to the amount of carbon in the molten metal bath to be theoretically in but slight excess thereto.

6. The method of claim 1, in which the oxidizing material added comprises carbon-reducible metal oxides.

7. The method of claim 1, in which a proportion of slagging materials is added to the said oxidizing material to facilitate the contacting of the said oxidizing material with the molten metal bath.

8. The method of claim 1, in which the pressure of said atmospheric gases is gradually reduced from atmospheric pressures to pressures at least approximating 15 to 35 millimeters of mercury.

9. The method of claim 1, in which the pressure of said atmospheric gases is reduced from atmospheric pressures to about 50 millimeters of mercury in a gradual manner and maintained at this pressure until the carbon content of the bath has been lowered to about 0.10 per cent and then reduced further to about 10 to 20 millimeters of mercury until the carbon content has been lowered the desired amount below 0.10 per cent.

10. The method of decarburizing high carbon ferro-chromium alloys which comprises heating the said alloy to temperatures approximating 1750 to 1850° C., adding thereto chromium oxide in amounts in slight excess to that theoretically computed to combine with the carbon, enclosing the molten bath from the atmosphere, circulating atmospheric gas over the surface of the bath, and continuing the heating of the bath under gradually reducing pressures of said atmospheric gases until the carbon content of the bath has been lowered to the desired amount, the said pressures being reduced gradually from atmospheric pressures to about 50 millimeters of mercury until the carbon content approximates 0.10 per cent and then being reduced gradually to between 10 and 20 millimeters and held there until the carbon content has been reduced to the desired percentage below 0.10 per cent.

11. The method of claim 10, in which the heating of the bath to the desired temperature is obtained by means of induced electrical currents adapted to maintain the bath in vigorous circulation at least sufficient to obtain uniform dispersion of the said chromium oxide throughout the bath.

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