

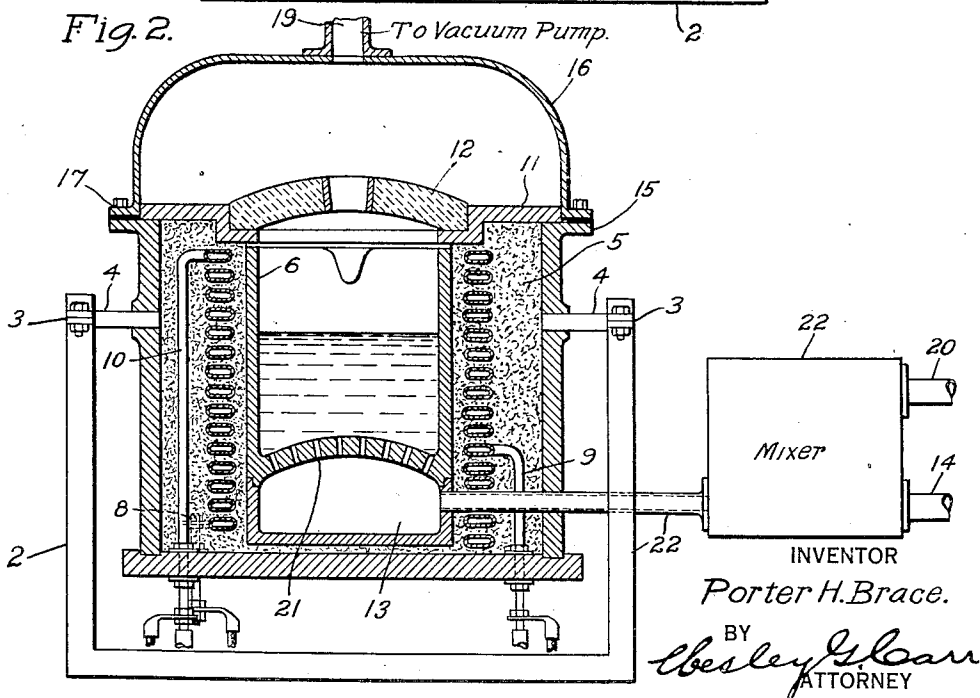
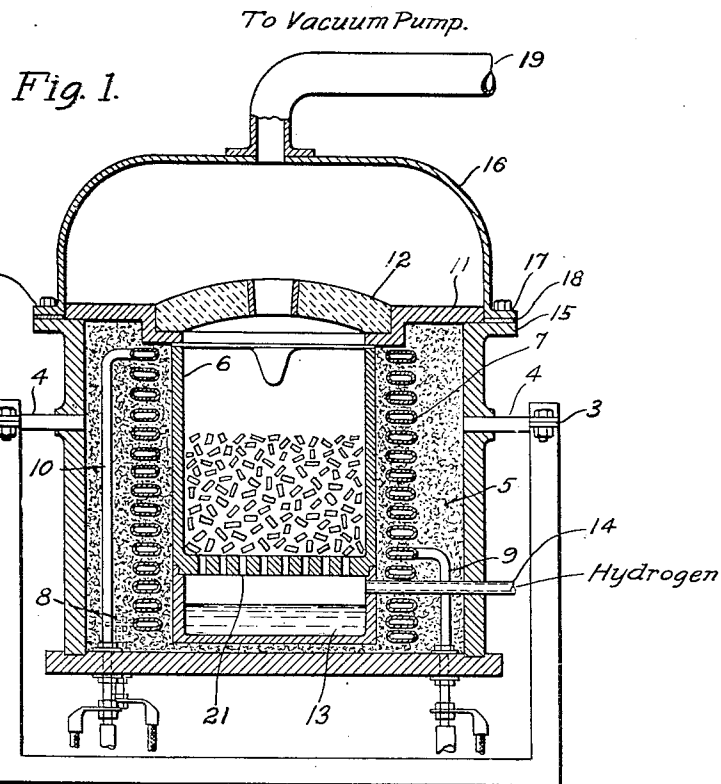
March 15, 1932.

P. H. BRACE

1,849,476

METHOD OF PRODUCING ALLOYS

Filed Feb. 27, 1928



UNITED STATES PATENT OFFICE

PORTER H. BRACE, OF WILKINSBURG, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE
ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

METHOD OF PRODUCING ALLOYS

Application filed February 27, 1928. Serial No. 257,145.

My invention relates to alloys and more particularly to alloys containing silicon as one of the principal ingredients.

5 An object of my invention is to provide alloys and especially iron-silicon alloys, that are comparatively free from carbon and other non-metallic impurities.

Another object of my invention is to provide a method of preparing ferrous alloys, and especially iron-silicon alloys, under reducing or non-oxidizing conditions.

10 A further object of my invention is to provide a method of preparing silicon alloys, and especially silicon steel, which consists essentially in passing vaporized elements, such as, silicon or silicon compounds, through a bed of heated iron in fragmentary form, or in the molten condition, under non-oxidizing or reducing conditions.

20 In producing silicon alloys, for instance, silicon steel, it has heretofore been the practice to melt the iron and then to add silicon or an iron-silicon alloy of high silicon content, such as ferro-silicon, to produce a silicon steel. This practice, however, has not been entirely satisfactory because ferro-silicon and commercially pure silicon are electric furnace products and contain an appreciable quantity of carbon.

30 I have made the discovery that when silicon of a fairly high degree of purity, say about 95%, and the metal with which an alloy is desired are heated under reduced pressure to a temperature slightly below the melting point of the metal, the silicon will vaporize and will be readily absorbed by the metal.

35 The same results may also be obtained by maintaining the metal or alloy to which it is desired to add silicon in the molten condition and passing vapors of a volatile silicon compound, such as a silicon hydride or a silicon halide, or a mixture of two or more of these compounds, through the molten metal. Hydrogen, hydrogeneous or other reducing gases, such as carbon monoxide, methane or

other hydrocarbons or a mixture of two or more of such gases may be added to the vaporized silicon, or if preferred, a neutral gas such as nitrogen may be utilized.

The temperature at which the metal is maintained will, of course, be dependent upon the volatile silicon compounds employed and upon the metal or metals with which an alloy is desired. In producing silicon alloys it is essential, however, that the temperature be sufficiently high to dissociate or reduce the silicon compound to silicon.

My improved process will be better understood by reading the specification in conjunction with the accompanying drawings in which:

Figure 1 is a vertical cross sectional view of an induction furnace, illustrating means for practicing my invention as applied to the production of silicon alloys when the metal with which an alloy is desired is in the solid state; and

Fig. 2 is a similar view, illustrating means for practicing my invention when the metal with which the alloy is desired is in the molten state.

Referring to Fig. 1 of the drawings, the induction furnace comprises a supporting frame 2 provided with bearings 3—3 to receive trunnions 4—4 carried by the furnace and providing means by which the furnace may be used for any purpose such as discharging its contents.

The furnace proper comprises a cylindrical shell or casing 5, a crucible 6 and an inductor coil 7 disposed circumferentially around the crucible 6. The crucible 6 may be of any material such as zirconium silicate. The inductor coil 7 comprises a plurality of turns of a conductor and is provided with a plurality of terminal posts 8, 9 and 10 which are connected to the uppermost, lowermost and intermediate coils respectively. The inductor coil employed in the furnace in which my process is practiced may be made hollow

and oval in cross section to fit into a small space and to facilitate cooling by passing water or other suitable cooling means there-through in order to keep the material of
5 which the coil is made at a safe operating temperature.

The intervening space between the crucible 6 and the casing 5 may be filled with a suitable pulverized material, such as zir-
10 conium silicate. An annular ring 11, offset at its innermost portion, constitutes the top of the casing, the offset portions providing a seat for a cover made of a suitable refractory material 12 which has an opening at its
15 central portion for purposes to be hereinafter described.

The furnace so far described is somewhat similar to furnaces disclosed in the copend-
ing applications of R. B. Lincoln, Serial No.
20 176,885, filed March 21, 1927, and Porter H. Brace, Serial No. 125,155, filed July 27, 1926, both of which are assigned to the Westinghouse Electric and Manufacturing Company.

As will be observed by reference to these
25 cases, the furnaces disclosed may or may not be provided with iron cores in their magnetic circuits. Furnaces of such type, which are operable to produce the melting of current conducting material, at low frequencies of
30 the order of 25 to 350 cycles per second, are particularly adapted for use in my improved process although it will be understood that any suitable furnace may be employed.

At the lower portion of the furnace, I pro-
35 vide a chamber 13 having a gas supply pipe 14 leading into the chamber and being separated from the crucible 6 by a perforated diaphragm 21.

In practicing my invention, in the furnace
40 shown in Figure 1 of the drawings, commercially pure silicon is placed in the chamber 13 and metal in scrap or fragmentary form is introduced into the crucible 6. A partial vacuum is maintained in the furnace and
45 when the silicon and metal are heated almost to the melting point of the metal, the silicon will have a higher vapor tension than the carbon, or other non-metallic impurities associated with it and its vapor will pass upward
50 through the perforated diaphragm 21 and be readily absorbed by the metal.

In making silicon-iron alloys by this process, for example, the silicon and iron are heated to a temperature of approximately
55 1400° C. At this temperature, the vapor tension of silicon is higher than that of most of the elements associated with it, and this is particularly true of carbon, so that by distilling silicon vapors into a bed of hot electrolytic iron, a means is provided for producing a silicon-iron alloy of a very high degree of purity under conditions suitable for preventing oxidation or the absorption of oxy-
60 gen by the resultant alloy. If desired, hydrogen or hydrogen bearing gases such as

methane may be passed through the pipe 14, chamber 13 and crucible 6 in order to preserve a reducing atmosphere.

The alloy, having been formed in the solid state, may then be melted by suitable means
70 in an atmosphere of a volatile compound of silicon such as silicon chloride, silicon hydride, silicon fluoride or other halogen or mixed halogen and hydrogen compounds of
75 silicon, or, if preferred, a mixture of the vapors of such compounds with hydrogen or halogens, such as chlorine or fluorine may be employed.

Figure 2 of the drawings illustrates the manner of practicing my invention when the
80 process is applied to producing an alloy of silicon when the metal or alloy to which the silicon is to be added is in the molten form. The metal or alloy is introduced into the crucible 6 either in the molten form or, if
85 desired, it may be melted in the furnace. Vapors of a volatile silicon compound such as the hydrides or halogen compounds of silicon, are then passed into the chamber 13 and through the openings 21 up through the
90 molten metal which is maintained at a sufficient temperature to dissociate the silicon compound forming the desired silicon alloy, the halogen or hydrogen being removed as a
95 gas, or as gaseous compounds of iron or other basic material that may be present.

It is sometimes desirable to add a reducing gas, such as hydrogen, or a hydrogen bearing gas to the silicon vapors of the volatile
100 silicon compound and pass the mixture through the molten metal, the silicon compound being either dissociated by the heat of the metal or reduced by the hydrogen so that the silicon thus obtained will be absorbed by the molten metal. When hydrogen
105 or other reducing gases are added to the volatile silicon compounds, the hydrogen and vaporous silicon compound are passed into a mixer 22 from a suitable source of supply through pipes 14 and 20, respectively. They
110 are intimately associated together in the mixer and are passed through the pipe 22 into chamber 13 and are then drawn through the molten metal.

By using my improved process, I am enabled to produce a silicon alloy, and particularly silicon steel, in a high state of purity and this is especially true with respect to carbon which has a deleterious effect on the
115 magnetic properties of the steel.

While I have described a specific embodiment of my invention, it will be understood that various modifications may be made therein without departing from the spirit of my invention. For example, my process is not
125 limited to the formation of silicon-iron alloys but is applicable to the production of silicon alloys of all kinds.

My process is also adaptable for forming alloys of iron or other metals with volatile
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metals, such as magnesium or aluminum. By utilizing the volatile chlorides of titanium, vanadium or chromium, I may also produce alloys of iron or other metals free from carbon or oxygen with these elements, in which case the alloys may be melted in an atmosphere of the chloride or other volatile compounds of these metals. The particular type of furnace utilized is also not of vital importance as any suitable furnace may be employed in which a partial vacuum can be maintained.

I, therefore, desire that only such limitations be placed upon my invention as are required by the prior art and the appended claims.

I claim as my invention:

1. The process of producing silicon alloys which comprises heating a metal or an alloy in a furnace to its melting point and passing a vapor containing silicon and a reducing gas through the molten metal while maintaining a partial vacuum in said furnace.
2. The process of forming silicon alloys which comprises maintaining a metal or alloy in a molten condition in a suitable furnace and passing vapors containing a volatile silicon compound and a reducing gas through the molten metal while maintaining a partial vacuum in said furnace.
3. The process of producing an iron-silicon alloy which comprises maintaining iron in a molten state in a suitable furnace, and passing a vapor containing a silicon compound and a reducing gas through the molten metal while maintaining a partial vacuum in said furnace.
4. The process of producing an iron-silicon alloy which comprises maintaining iron in a molten state in a suitable furnace, and passing a vapor containing a silicon compound and hydrogen through the molten metal while maintaining a partial vacuum in said furnace.
5. The process of producing iron-silicon alloys in a high state of purity which comprises melting iron in a suitable furnace, passing a vapor containing silicon through the molten metal from a separate vessel having passages leading into the furnace and maintaining the pressure in the furnace below atmospheric pressure but at a pressure above that at which substantial amounts of impurities in the silicon will volatilize.
6. The process of producing iron-silicon alloys in a high state of purity which comprises placing iron in a suitable furnace, heating it to a temperature slightly below its melting point and passing a vapor containing silicon through the metal from a separate vessel having passages leading into the furnace and maintaining a pressure in the furnace below atmospheric but at a pressure above that at which substantial amounts of impurities in the silicon will vaporize.

7. The process of producing an alloy which comprises heating a metal or alloy in a furnace to its melting point and passing a vapor containing an additional alloying element and a reducing gas through the molten metal while maintaining a partial vacuum in said furnace.

In testimony whereof I have hereunto subscribed my name this 20th day of February, 1928.

PORTER H. BRACE.

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