Jan. 7, 1964 E. J. KOHLMEYER ETAL 3,117,175

APPARATUS FOR MAKING ALUMINUM-SILICON ALLOYS

Original Filed Dec. 11, 1959 2 Sheets-Sheet 1

Fig. 1.

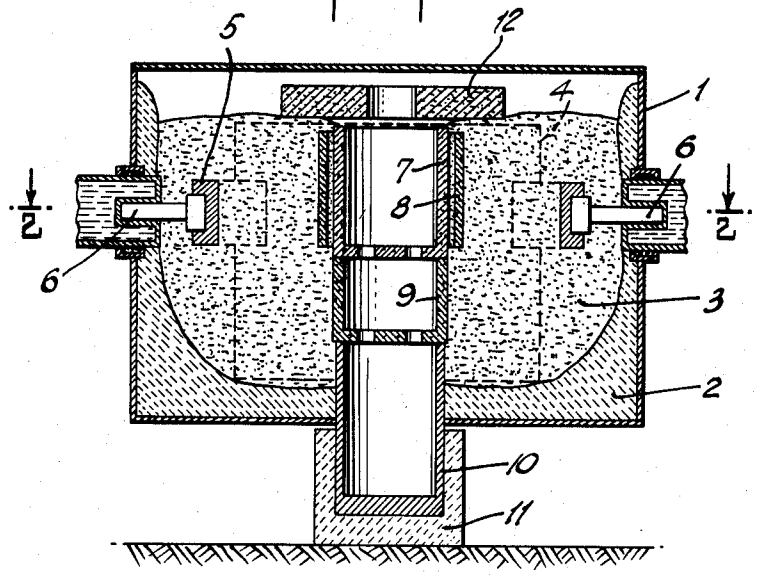
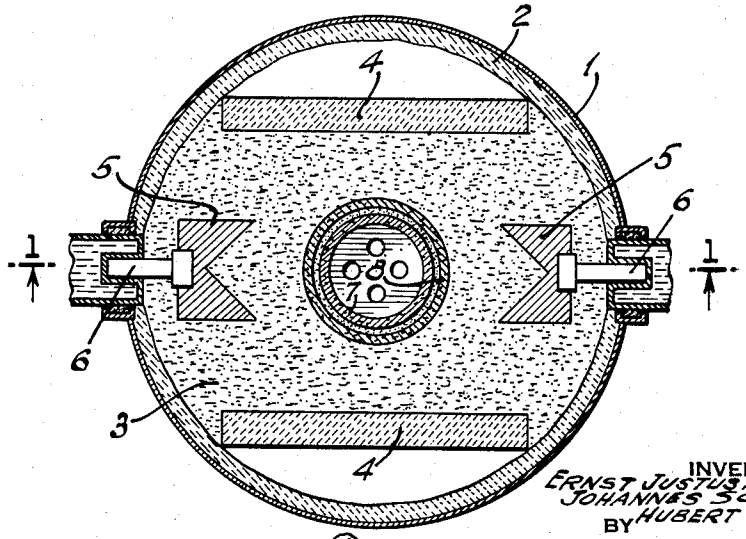


Fig. 2.



INVENTORS:
ERNST JUSTUS KOHLMEYER
JOHANNES SCHMITT
HUBERT WITTNER
BY
Morrison, Kennedy & Campbell
ATTORNEYS:

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Fig. 3.

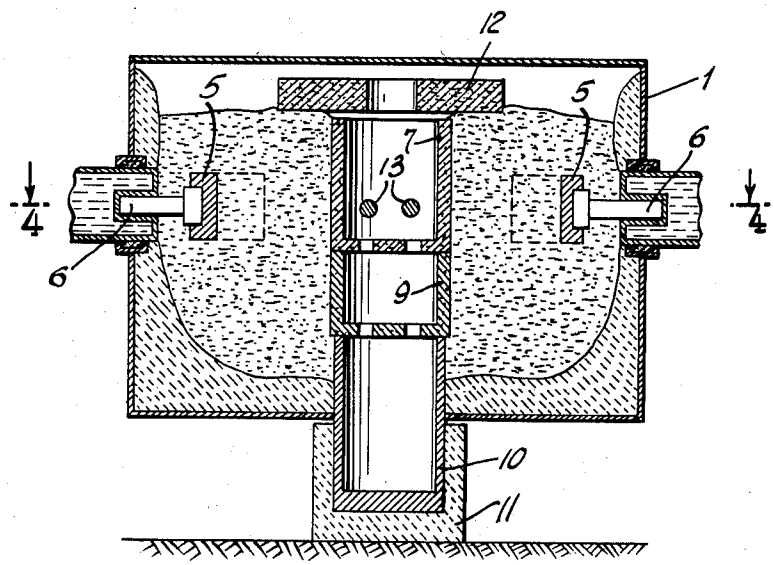
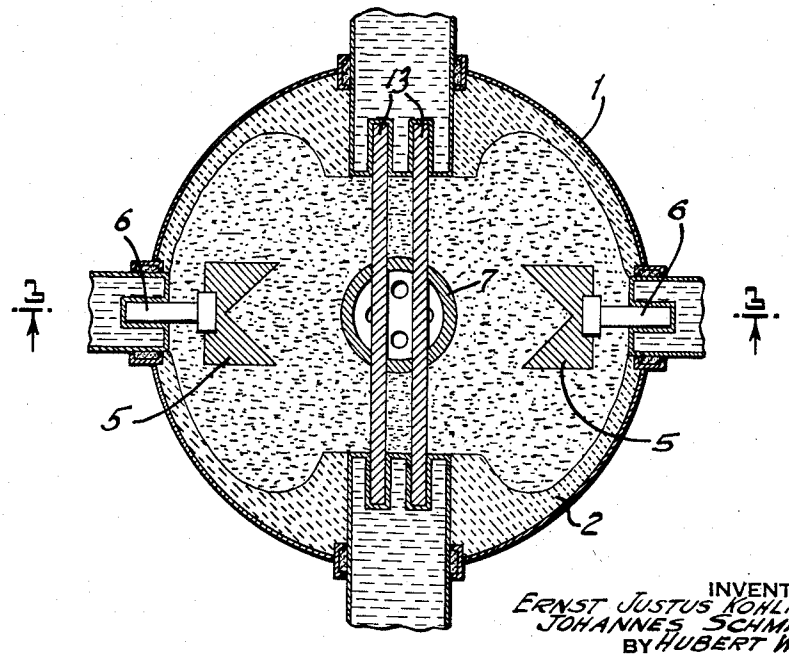


Fig. 4.



INVENTORS:
ERNST JUSTUS KOHLMEYER
JOHANNES SCHMIDTT
BY HUBERT WITTNER

Morrison, Kennedy & Campbell
ATTORNEYS:

United States Patent Office

3,117,175

Patented Jan. 7, 1964

3,117,175

APPARATUS FOR MAKING ALUMINUM-SILICON ALLOYS

Ernst Justus Kohlmeyer, Berlin-Grunewald, and Johannes Schmitt and Hubert Wittner, Rheinfelden, Baden, Germany, assignors to Aluminium-Industrie-Aktien-Gesellschaft, Chippis (Switzerland), Chippis, Switzerland, a joint stock company of Switzerland

Original application Dec. 11, 1959, Ser. No. 858,923. Divided and this application Aug. 30, 1960, Ser. No. 52,982

Claims priority, application Switzerland Aug. 31, 1959

4 Claims. (Cl. 266—24)

This application is a division of our copending application Serial No. 858,923, filed December 11, 1959.

For many decades aluminum-silicon alloys have been obtained by reduction of oxidic raw-materials of aluminum and silicon by means of carbonaceous reduction means in electrothermal furnaces. In nature there are inexhaustible raw-material sources which are found at many places. The raw-materials are mostly kaolin, clay, and the like.

The process for making aluminum alloys electrothermally is presently carried out in furnaces with vertical electrodes, and has been empirically developed. Nevertheless, in the course of recent years the aluminum-content of the aluminum-silicon alloys obtained has gradually been raised. About 30 years ago an aluminum-content of 65% was considered as the upper limit which could be reached. Later on it was raised up to 70%, but it has been considered impossible to obtain an aluminum content higher than 70–72% (calculated on the sum Al+Si). Efforts to get an alloy with a higher content of aluminum have always resulted in a product which was composed of aluminum carbide and aluminum-silicon alloy.

Our present invention relates to apparatus for making substantially carbon-free aluminum-silicon alloys with more than 72% aluminum by electrothermal reduction of raw-materials containing alumina and silica.

We have found the production of carbon-free or carbide-free, aluminum-silicon alloys by direct reduction of the raw materials in an electric furnace represents chiefly a thermal problem which cannot be solved in the electrothermal furnaces generally used at present. As the temperature in the electric furnaces such as they are presently constructed is high and fluctuating, there are in these furnaces temperature-conditions which cannot be kept under control. At uncontrolled high temperatures carbides are formed by reaction of carbon or carbon-containing gases with alumina and silica or with aluminum and silicon as soon as one tries to produce aluminum-silicon alloys with a higher content of aluminum than 65%. We have found that, as set forth in said copending application Serial No. 858,923, aluminum-silicon alloys with 72% aluminum and more can be obtained if the following conditions are simultaneously observed:

(1) The reduction of the oxides of aluminum and of silicon must be carried out within a narrow temperature zone in which the speed of the reactions which lead to the formation of the aluminum-silicon alloy is great, in which already-formed carbides of alumnium and of silicon react with alumina and silica to form metal, and in which the volatilization losses of the aluminum and of the silicon are still small. This zone of temperatures extends from about 2050° C. up to about 2200° C. When observing an upper temperature limit of about 2200° C. the vaporization losses are still small; at over about 2200° C. the volatilization of the aluminum and of the silicon rises rapidly.

(2) The raw-material mixture must be heated as quickly as possible to the temperature zone which is necessary for the metal liberation in order to pass so quickly beyond the temperature zone of 1600–2000° C. (which is favorable for the formation of carbides) that virtually no formation of carbides takes place.

(3) The formed aluminum-silicon alloy must be removed as soon as possible after its formation continuously from the hot reduction-room and cooled down to a temperature at which the carburization by reaction with carbon or carbonaceous gases under formation of carbides can no longer take place. Care must therefore be taken that the aluminum-silicon alloy flows as quickly as possible out of the reduction-room.

The simultaneous fulfillment of the three above mentioned conditions can be attained by the process set forth in said copending application Serial No. 858,923. According to that process, the raw-material mixture is charged in such a manner that overheating is prevented in the reduction-room; in other words, the manner in which the raw-material mixture is added is such that the temperature in the reduction-room does not rise to a level at which the volatilization losses of aluminum and of silicon are too great, that is to say to a temperature over 2200° C. Preferably the upper limit of the temperature is kept under this temperature of 2200° C. The purpose can be attained by keeping the temperature of the raw-material mixture when charge dwell enough under the upper admissible limit in the reduction-room. The raw-material mixture may be, for instance, at room-temperature; though, depending on the size and on the construction of the furnace, it may be advantageous to charge the raw-material in a pre-heated state. Furthermore, it is necessary to charge the raw-material mixture substantially continuously, i.e., either continuously or at short time intervals.

Moreover, care should be taken that the formed molten aluminum-silicon alloy leaves the hot zone of the reduction-room continuously without trickling or flowing through a less hot layer of raw-material mixture in which aluminum-carbide could be formed. With the known electrothermal process for making aluminum-silicon alloys the formed alloy flows through a still unreacted layer of charge, in which layer the danger of carburization, that is to say of carbide formation, exists.

According to our invention the reduction zone is separated from the lower aluminum-silicon alloy collecting room by a room in which the aluminum-silicon alloy becomes cooled as quickly as possible to a temperature (for instance between its melting point and 1600° C.) at which a reaction between the aluminum-silicon alloy and carbon with formation of carbide can no longer take place. The carbon could be supplied either by the wall of the collecting-room or by particles of the raw-material mixture which become dragged along out of the reduction-room by the aluminum-silicon alloy flowing down or which simply fall out of the reduction-room into the collecting-room. Consequently there must be a separating room between the reduction-room and the collect-room. Furthermore, when carrying out the process according to our invention heat is desirably supplied to the reduction-room by electric resistance heating. Most advantageously the reduction-room is surrounded by a conducting mass, for instance, of finely divided carbon, through which an electric current is conducted.

Also, heating-rods or other heating conductors may be used. Care should be taken that the heat be supplied laterally to the reduction-room, but one may also additionally dispose heating-rods through the raw-material mixture itself in the reduction-room. Also, inductive heating may be utilized. There are many possibilities for heating the raw-material mixture to the reaction tem-

perature without using electric-arc electrodes. It is essential that there be a sufficient heat supply to keep the most favorable temperature zone.

The speed of charge of the raw-material mixture must be so controlled that the heat supplied to the furnace is consumed by the quick heating and the melting of the raw-material mixture and by the reduction of the oxides as well as by compensating for the losses through the reaction-products carried off. In order to maintain the favorable temperature range we have found that it is advantageous to charge the raw-material mixture in such a manner that the reduction-room be always kept full.

The physical condition of the raw-material mixture to be charged has, of course, an influence on the progress of the reaction. Normally with such processes, the raw-material mixture is charged in the form of briquettes. When carrying out the process according to our invention, especially uniform progress of the reaction with a maintained heat balance is obtained by charging the raw-material as pellets of about 15–20 mm. diameter. To make the pellets, the raw-material mixture is, for instance, mixed with 20–25% of water and poured in a known manner on a rotating disc-plate or treated in a rotating drum. It may be advantageous to add to the raw-material mixture a few percents of sulphur as sulphides, sulphates, or other sulphur compounds in order to obtain a quicker melting.

At the suitable temperature of, for instance, about 2100° C., there takes place a quick melting as well as a quick reduction. When continuously charging further raw-material mixture directly onto the surface of the mixture which has just been charged and is continuously moving down, the new charge acts to some extent as a coolant on the melt, thereby preventing overheating. Since a melting substance cannot be heated over its melting point, a constant temperature in the melting-room (reduction-room) itself will always prevail.

The reduction-room may be advantageously disposed vertically above the collecting-receptacle. With such a disposition the aluminum-silicon alloy can reach the collecting-receptacle most quickly—by a free fall, for example. If, for instance, the reduction zone is located in the lower part of a reduction-crucible which is disposed at a sufficient distance above the collecting-room, so that the molten aluminum-silicon alloy can cool down sufficiently during its free fall after leaving the reduction zone, and if, through this disposition, the collected metal be sufficiently separate in space from the perforated bottom of the crucible, conditions are attained which allow the carrying out of the process according to our invention.

The purpose of the separating-room under the reduction-room is to remove the molten aluminum-silicon alloy as quickly as possible from contact with the reacting charge. Of course, for instance, perforated non-reactive intermediate bottoms may be disposed in this separating-room, which bottoms prevent an excessive reflection of heat from the reduction-room downwards or fully prevent such a reflection. The separating-room may be also partly filled with a bed of lumps or grains of a material (for instance lumps of corundum) which has a poor thermal conductivity and does not react with the molten aluminum-silicon alloy. Such lumps or grains may be disposed on perforated intermediate bottoms.

Furthermore, the mounting of other types of baffles between the reduction-room and the collecting-room may be advantageous.

Instead of a vertical arrangement one may choose a disposition at which the aluminum-silicon alloy flows obliquely into the collecting-receptacle. With such a disposition one should suitably take care that the wall along which the aluminum-silicon alloy flows down has such a composition or such a temperature that it cannot react with the aluminum-silicon alloy and form carbide.

In some cases it may be advantageous to dispose cooling elements in the separating-room in order to accelerate the cooling of the aluminum-silicon alloy. These cooling elements may, for instance, be rods made from inert material with a filler of copper, the heat being withdrawn from these rods outside the furnace by means of a cooling liquid.

It may be also advantageous to provide the collecting receptacle with a device allowing either a heating or a cooling, so that the temperature which is necessary for maintaining the heat-balance can be controlled.

When carrying out the process, one may, of course, use as a collecting-receptacle a channel or a pan from which the aluminum-silicon alloy flows continuous into another receptacle or even into a casting device, for instance into a pig-casting machine.

As the raw-material mixture must be heated in as short a time as possible to the reduction temperature range and must pass as quickly as possible through the temperature zone of 1600° to 2000° C. (which is favorable for the formation of carbides) it is advisable at the begining of the operation to heat the reduction-room to a temperature of, for instance, 2050° to 2200° C. before charging the raw-material mixture.

Of course, the process and apparatus can also be applied when one wishes to make an aluminum-silicon alloy which contains less than 72% aluminum, for instance down to 65% aluminum or even 60% aluminum. Even though aluminum-silicon alloys which contain more than 60% or even more than 65% aluminum in the usual electric furnaces can be obtained by known processes, the present process and apparatus are superior to the known processes and apparatus for making such aluminum-silicon alloys, as the reduction can be much better controlled so that the process is also superior with respect to the expenditure of energy.

The aluminum-silicon alloys obtained according to our invention may have a rather high content of iron (for instance as in the ferro-silico-aluminum), of titanium, and of other elements.

In the drawings:

FIG. 1 is a vertical sectional view of one form of apparatus embodying the invention;

FIG. 2 is a horizontal sectional view thereof;

FIG. 3 is a vertical sectional view of a modification; and

FIG. 4 is a horizontal sectional view thereof.

In FIGS. 1 and 2 there is illustrated an embodiment of the invention in the form of a small experimental furnace of a capacity of about 80 kilowatts. The iron furnace-shell **1** is provided with a lining **2** of fire clay and filled with finely divided carbon **3**. Two parallel walls **4** built up with magnesite bricks limit the inner room at both sides of the current-supply nipples **5** made of graphite and of the water-cooled steel electrodes **6**. A cylindrical crucible **7** made of graphite is disposed in the furnace at such a height that its lower part which serves as the reduction room is at the same height as the current-supply nipples **5**. The crucible **7** is formed with a perforated bottom as shown, and is surrounded by a cylinder **8** made from electrode-carbon, which cylinder serves to transfer the heat uniformly to the reduction room. Under the reduction crucible **7** there is disposed an intermediate vessel **9** which is also made of graphite and has a perforated bottom. Under the intermediate vessel there is a collecting receptacle **10** made of clay-graphite. The lower part of the receptacle **10** projects downwards out of the furnace and is surrounded by a mantle **11** of fire clay powder which protects it against a too great cooling. On the reduction crucible **7** there is laid a covering plate **12** made of electrode-carbon with a central hole for the charging.

As can be seen, the reacting charge in the crucible **7**, which is maintained by resistance heating at a temperature of for instance 2050° to 2200° C., is separated in space from the aluminum-silicon alloy which collects in the collecting vessel **10**. The aluminum-silicon alloy

formed in the crucible flows out of the reaction chamber through the vessel **9** into the collecting receptacle **10** (a part of which is disposed outside the furnace) before it can carburize. The temperature of the collecting receptacle is only about 900° C., that is, about 1150° C. to 1300° C. below the temperature of the reduction zone, so that the aluminum-silicon alloy does not take up carbon in the collecting receptacle.

FIGS. 3 and 4 show another example of a small experimental furnace embodying the invention. The arrangement is the same as in the experimental furnace shown in FIGS. 1 and 2, except that the two walls from magnesite bricks are not used; but current connections are provided for the additional heating by means of the graphite heating-rods **13**.

In furnaces such as illustrated we succeeded in obtaining among others an aluminum-silicon alloy with 76.0% aluminum and 23.1% of silicon; the remainder being composed of the usual impurities (iron, titanium, and so on) which occur in electrothermally produced aluminum-silicon alloys. This aluminum-silicon alloy was obtained from a mixture of the following raw-materials:

	Percent
Raw kaolin	27.4
Burnt kaolin	23.8
Alumina	23.6
Silica (quartz)	2.1
Charcoal	23.1

The mixture was pelletized to grains of 15 to 20 mm. cross-section, which sustained without damage a fall from a height of 1.5 to 2 meters.

Before introducing the raw-material mixture, the reduction crucible **7** was heated to a temperature of 2100° C. to 2200° C. and kept at this temperature during the continuous charging of raw-material mixture.

Since certain changes in the constructions set forth, which embody the invention, may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electric resistance furnace unit for making aluminum-silicon alloys by electrothermal reduction of oxidic raw materials of aluminum and silicon by means of a carbonaceous reduction agent, comprising a furnace having an outer furnace peripheral wall, a vertical reduction chamber made of graphite and located inside said furnace wall, means for heating said chamber to a temperature at which the oxidic materials of aluminum and silicon will be reduced by means of a carbonaceous reducing agent admixed therewith to form the aluminum-silicon alloy, comprising a body of finely divided carbon in which said reduction chamber is embedded substantially filling the space between said chamber and said peripheral furnace wall, and electrode means contacting said body of carbon for supplying heating current to said body of carbon, whereby said body of carbon serves as a horizontal electrical resistance between the lower part of the reduction chamber and said electrode means, said reduction chamber having an opening near the top and a flat bottom containing a plurality of spaced perforations through which the molten aluminum-silicon alloy is discharged by gravity as soon as it is formed in said reduction chamber, a separating chamber inside said furnace wall disposed directly below said reduction chamber and embedded in said body of carbon to receive the molten aluminum-silicon alloy discharged from said reducing chamber, and a collecting chamber for the molten aluminum-silicon alloy disposed directly below said separating chamber in position to receive the molten aluminum-silicon alloy discharged from said separating chamber, means for maintaining said collecting chamber at a temperature at which the reaction of the aluminum and silicon in the alloy with the carbon to form the carbides thereof cannot take place, and comprising means for supporting said collecting chamber with its upper part projecting partially into said furnace and embedded in said carbon and its lower part projecting through the bottom of the furnace, and a thermal insulation around the projecting lower part of said collecting chamber, and means for maintaining said separating room at a temperature which is intermediate the temperature in said reduction chamber and the temperature in said collecting chamber, and which is below the temperature at which a reaction with the aluminum-silicon alloy and carbon with formation of carbide can take place and including said body of carbon in which said separating chamber is embedded.

2. An electric resistance furnace unit as described in claim 1, wherein said electrode means include electrodes located substantially at the level of said reducing chamber and equally spaced around said reducing chamber, said electrodes constituting the main means for supplying heating current to the body of carbon, said opening near the top of said reducing chamber being uncovered and said reduction, separating, and collecting chambers having substantially the same internal diameters.

3. An electric resistance furnace as described in claim 1, wherein said separating chamber has a perforated bottom wall forming a shield to prevent excessive transfer of heat from the reduction chamber to said collecting chamber.

4. An electric resistance furnace unit as described in claim 1, wherein said electrode means includes electrodes located substantially at the level of said reducing chamber and equally spaced around said reducing chamber, said electrodes constituting the main means for supplying heating current to the body of carbon, said opening near the top of said reducing chamber being uncovered and said reduction, separating, and collecting chambers having substantially the same internal diameters, said separating chamber having a perforated bottom wall forming a shield to prevent excessive transfer of heat from the reduction chamber to said collecting chamber.

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