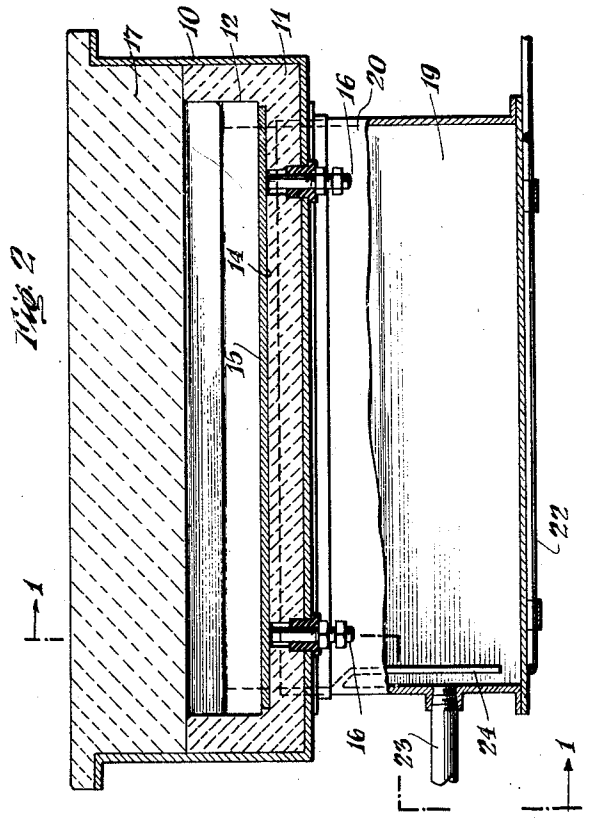
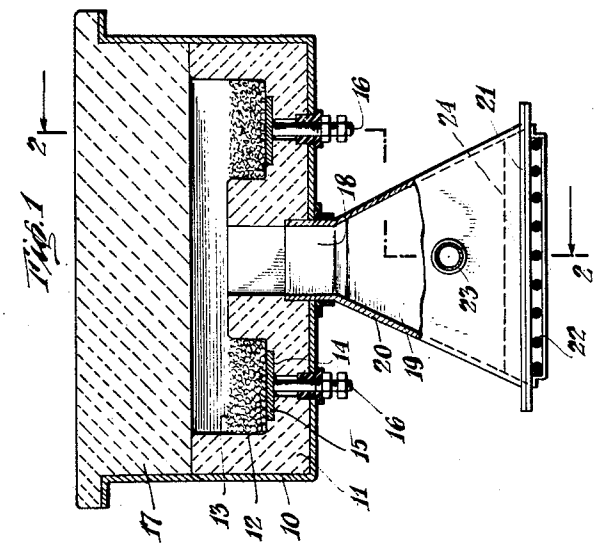
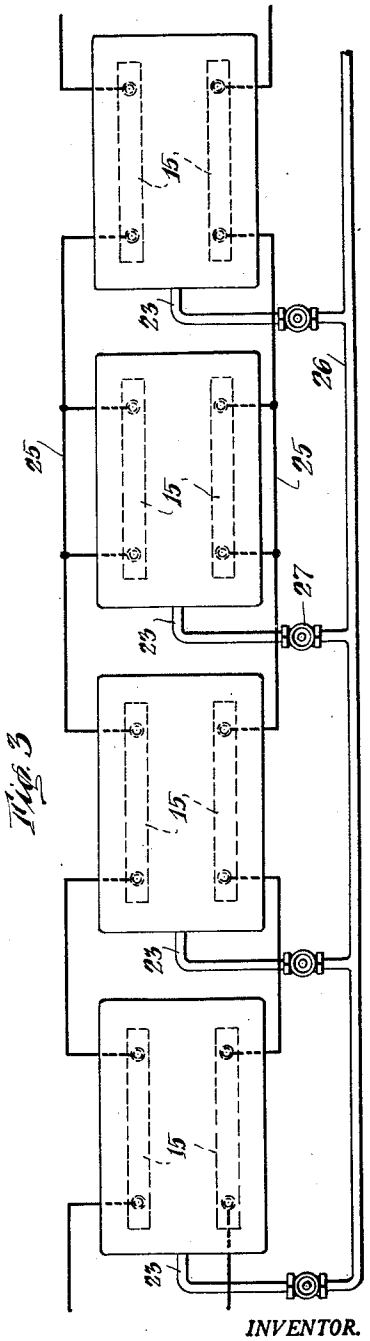
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FURNACE FOR REDUCING AND DISTILLING VOLATILE METALS

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FURNACE FOR REDUCING AND DISTILLING VOLATILE METALS

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This invention relates to apparatus for use in the production and recovery in solid or liquid form of volatile pyrophoric metals from their oxides and other reducible compounds.

The invention has particular application in the reduction of oxides and other reducible compounds of such volatile metals as magnesium, sodium and potassium by the use of a non-volatile reducing agent, preferably a non-volatile reducing metal, and under operating conditions whereby the reduced volatile metal is withdrawn from the reducing zone in the form of vapors and condensed in a cooler part of the apparatus.

In recent years this general process has been used extensively in the production of metallic magnesium from its oxides and other reducible compounds by the use as a reducing agent of ferrosilicon, silico-aluminum, silico-ferro-aluminum, or another alloy which supplies silicon or another reducing metal to displace magnesium from its oxide or other reducible compound when heated therewith at high temperature. Other reducing agents, such as calcium carbide, have also been proposed. In this application of the general process, one of the difficulties that has been encountered has to do with the supply of heat to the reaction and the effect of the heated volatile vapors of the reduced metal upon the apparatus.

Many types of furnaces have been tried for carrying out this reaction, but these have been unsatisfactory for various reasons and do not give the results desired whether heated from the outside or from the inside. Heavy tubular retorts made from special alloy steels heated from the outside have a short life and are expensive. They also have a tendency to collapse when the process is carried on under a reduced pressure or vacuum to promote the reaction and vaporization of the reduced metal. This collapse can be prevented by placing refractory material inside the tubes but this expedient greatly reduces the thermal effect.

When direct heating is employed, as in arc furnaces, the metal vapors interfere with the operation. Likewise, when resistance furnaces of conventional forms are employed, the metal vapors interfere with the resistance of the elements and their life is short requiring frequent replacements.

It is an object of the present invention to overcome these drawbacks of the earlier practices and apparatus and to effect marked savings in the heat requirements and in the operating and maintenance costs of the apparatus involved.

It is a further object of the invention to provide

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an improved arrangement for condensing and recovering the vaporized metal.

I have found that the difficulties encountered in the use of resistance furnaces in carrying out the process can be eliminated by locating the resistance heating elements underneath the material to be reduced, so that these heating elements are out of the way of the metal vapors and are protected from the metal vapors by the material undergoing reduction.

As to the material for the heating elements, where for example magnesium or sodium is to be produced ordinary iron or steel may be placed or cast in situ on the bottom of the reaction zone of the furnace. Alternatively, when a non-volatile metal is employed as the reducing agent, such metal or an alloy thereof can be used for the heating element. For example, ferrosilicon or silico-aluminum may be employed when reducing magnesium oxide or another reducible magnesium compound. Resistor elements formed of such metals are so inexpensive that they can be replaced even after each operation.

There is no danger that an operation may be stopped due to burning out of a resistance element, because even if a part of the heating element becomes over-heated and brought to fusion the current will still continue to pass through this molten part of the conductor until equilibrium is again restored.

While the metals cited in the above examples have the desirable advantage for use as resistors that they are cheap and may be frequently renewed without greatly adding to the cost of the operation, it is to be understood that the invention is not limited to the use of such resistors. The desirable advantages of longer life of the resistance elements and non-interference by the vapors of the reduced metal with the resistivity characteristic of the resistors may be realized by resort to any resistor body that is substantially non-volatile at the temperature at which the pyrophoric metal will freely vaporize, that is, a body that is non-volatile and remains in a solid state at the temperature employed. Among others that may be mentioned are the various nickel-chromium alloys having high resistivity. Even carbon resistors may be used, in which case it will usually be desirable to provide some means for protecting the carbon body from abrasion by the charge placed thereon or from damage that might otherwise take place, during cleaning of the reducing zone preparatory to introducing a fresh charge.

Another feature of the invention resides in the

arrangement of the condensing zone in such relation to the reducing zone that the vapors of the reduced metal are led from the reducing zone into a large space where the rate of flow of the vapors is retarded thereby increasing their tendency to condense upon cooling surfaces defining the space or disposed therein. Advantageously cooling surfaces are provided adjacent or at the lower side of the enlarged space so that the movement of the vapors toward the cooling surfaces will be aided by gravity, and, if other considerations do not interfere, access to the condenser and removal of the condensed metal may be facilitated by providing a removable closure which is positively cooled and constitutes a lower wall portion of the condensing chamber which may be removed and replaced from time to time or substituted by a new closure.

Other advantages and features of novelty will be apparent from the following description and accompanying drawings in which:

Fig. 1 is a vertical cross-section taken along the line 1—1 of Fig. 2 through a furnace embodying the improved apparatus features of the present invention and which will be referred to hereinafter in describing a typical application of my improved process;

Fig. 2 is a vertical longitudinal section taken along the line 2—2 of Fig. 1; and

Fig. 3 is a plan view showing a series of furnaces of the type shown in Figs. 1 and 2 arranged for electrical connection in a series circuit.

The furnace comprises a frame or casing 10 provided with a refractory lining 11 in which is formed a pair of hearths or troughs 12 adapted to receive, as at 13, the material prepared for the reaction, such for example as an intermixture of magnesium oxide and ferrosilicon, either loosely intermingled or as briquettes. The bottom of each trough 12 is shown as recessed to form an elongated cavity or channel 14 to receive an electric resistance element 15. Current is supplied to the resistance elements 15 through terminal connections 16. The furnace is closed by a cover 17 which is removable to permit charging of the furnace and removal of residue after the operation.

In the form shown, the furnace is generally rectangular, and the pair of troughs 12 extend longitudinally thereof on each side of a central longitudinally extending throat 18, through which the metal vapors formed in the reaction zone 13 are withdrawn. The throat 18 communicates with a condenser 19 formed by diverging side walls 20 and a flat bottom wall 21. The metal vapors are cooled down and condensed on the side walls of the condenser 19 and on the bottom wall 21.

Preferably the removable bottom wall 21 is kept at a lower temperature than the walls 20, in order to increase the condensation of the metal vapors on the removable bottom. For this purpose, cooling elements are provided which are shown by way of example as water pipes 22.

The furnace is preferably operated under reduced pressure, and is connected by a pipe 23 to a vacuum pump or equivalent means, not shown. The baffle 24 serves to prevent the metal vapors from passing to and clogging the pipe 23 or from passing to the pump.

Due to the arrangement of the condensing chamber with downwardly diverging side walls, thereby creating an expanded space, and to the provision of the cooling bottom plate directly beneath the elongated discharge passage or throat

18, the metal vapors evolved from the reducing zone and passing downwardly through the throat 18 are largely brought into contact with the cooled bottom plate or previously solidified metal collected thereon and condensed, forming solid masses of the reduced metal.

The electric resistance element 15 may be an iron bar or other suitable resistor body placed in the recessed channel in the bottom of the reaction zone or it can be cast into position by pouring molten iron or other suitable metal into the recess 14. This casting expedient is preferred when material of low tensile strength is used as the resistor, for example a silico-ferro-aluminum alloy with high silicon content.

The electric resistance may be highly increased by replacing the bar or molten pool by finely divided or granular material capable of passing an electric current in the manner of a resistance element, for example granular silicon or ferrosilicon. The furnace is preferably operated under high current density and low voltage, and hence a plurality of furnaces are preferably arranged in a series circuit as shown in Fig. 3. For purposes of charging and discharging any of the series, the resistance elements thereof may be short-circuited by means of a shunt bar 25. The pipes 23 from the individual furnaces are shown as connected to a common pipe 26 leading to the vacuum pump and provided with suitable valves 27 for cutting off and turning on the vacuum to the individual furnaces.

It will be understood that the cross-section of the resistor bodies will be so selected with relation to the resistivity of the material used to form the resistor body as to insure that the current passing through the resistor will develop heat sufficient to maintain the desired heat input to the reducing zone. When carrying out the reduction of magnesium from its reducible compounds, satisfactory operating conditions will be maintained in the reducing zone if the resistor bodies are maintained at a temperature in the neighborhood of 1150° C. or at lower temperatures when a reduced pressure or vacuum is maintained.

Where herein and in the appended claims I have used the term "pyrophoric" it is to be understood as including those metals that will burn spontaneously in air when exposed to air in finely divided form, examples being magnesium, sodium, potassium, and lithium.

The term "silicon" as used in certain of the appended claims is intended to include besides metallic silicon any of its alloys that may be used in effecting the thermic reduction of magnesium oxide and similar compounds, for example ferrosilicon, silico-aluminum, and silico-ferro-aluminum.

Where in the appended claims I have referred to the term "oxides of the pyrophoric metals," it is to be understood that this term is used generally to include not only the various oxides but also other compounds of these metals that are reducible by thermic reduction with non-volatile reducing metals such as silicon and its alloys or by other suitable non-volatile reducing agents such as calcium carbide.

Various changes may be made in the form of the apparatus without departing from the invention which is not to be deemed as limited otherwise than as indicated by the appended claims.

I claim:

1. An apparatus for producing and recovering

volatile pyrophoric metals from their oxides by thermic reduction with a non-volatile reducing agent, comprising an enclosed heating chamber, a solid metallic resistor body disposed in the floor of said chamber for supporting a charge to be reduced above and in contact with said resistor body and means for withdrawing vapors of said metal from said chamber and out of contact with said resistor body.

2. An apparatus for producing and recovering volatile pyrophoric metals from their oxides by thermic reduction with a non-volatile reducing agent, comprising an enclosed heating chamber, an elongated solid metallic resistor body disposed in the floor of said chamber and cooperating with the walls of said chamber in defining a charge-receiving space, a condenser associated with said chamber and means defining a passage thereto communicating with said heating chamber at a point remote from the resistor, whereby vapors of the reduced metal evolved from said charge will be led to and through said passage into said condenser without coming into contact with said resistor body.

3. An apparatus for producing and recovering volatile pyrophoric metals from their oxides by thermic reduction with a non-volatile reducing agent, comprising an enclosed heating chamber, an elongated solid resistor body disposed in the floor of said chamber and cooperating with the walls of said chamber in defining a charge-receiving space, a condenser associated with said chamber and means defining a passage thereto communicating with said heating chamber at a point remote from the resistor, whereby vapors of the reduced metal evolved from said charge will be led to and through said passage into said condenser without coming into contact with said resistor body, and means defining a cooling surface in opposed relation to and beneath the outlet from said passage, whereby vapors of the reduced metal led through said passage are caused to pass under the influence of gravity into contact with said cooling surface.

4. An apparatus for producing and recovering volatile pyrophoric metals from their oxides by thermic reduction with a non-volatile reducing agent, comprising an enclosed heating chamber, a pair of parallelly arranged, charge-receiving hearths disposed therein, an elongated solid resistor body disposed in the floor of each of said hearths for supporting a charge to be reduced above and in contact with each of said resistor bodies, means defining an elongated vapor offtake opening through the bottom of said chamber intermediate and in parallel relation to said hearths, a condenser communicating with said opening, and means for directing vapors of the reduced metal upward away from said resistor bodies in their travel to said offtake.

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