Sept. 13, 1960 R. J. GARMY 2,952,723

APPARATUS FOR CONTROLLING THE ATMOSPHERE IN AN ELECTRIC FURNACE

Filed July 10, 1957 4 Sheets-Sheet 1

Fig. 1.

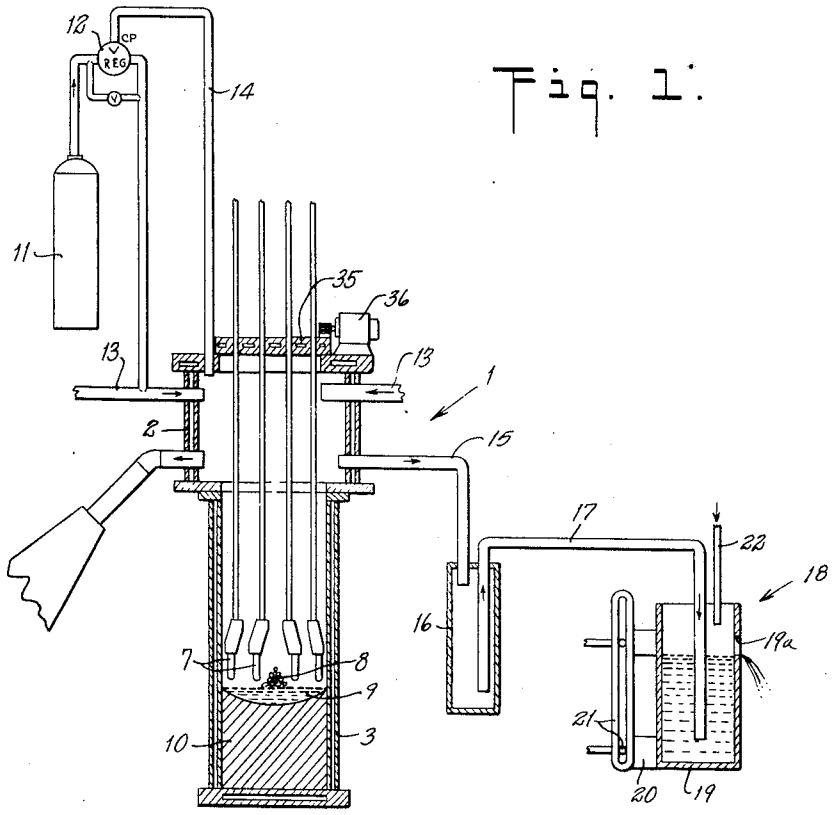
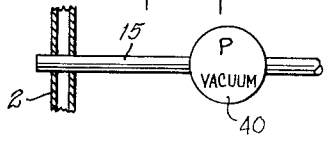


Fig. 1a.



INVENTOR.
ROBERT J. GARMY
BY
W. H. Woodlief
ATTORNEY

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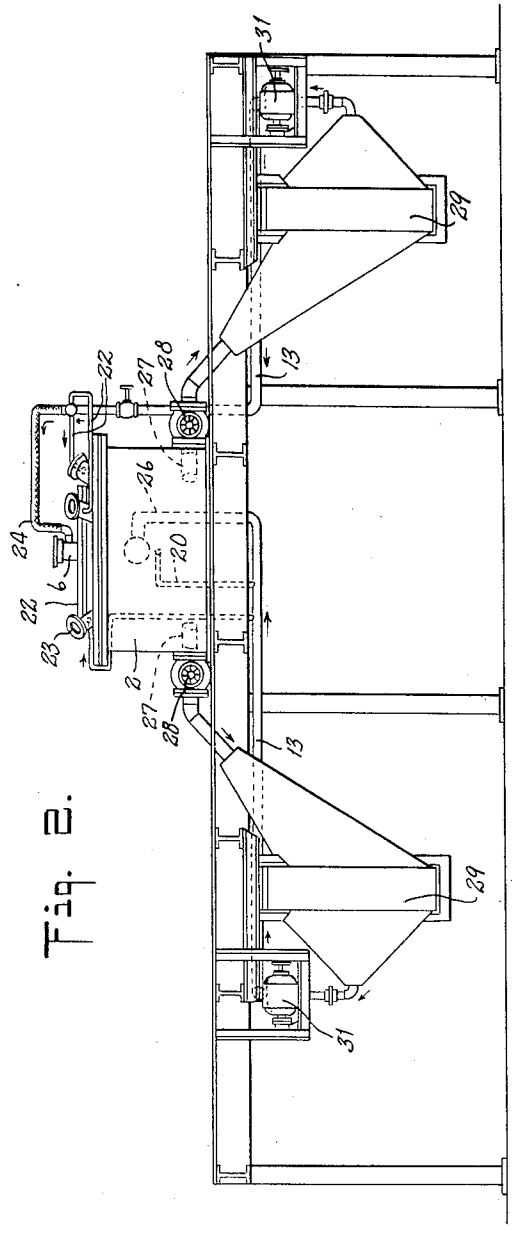


Fig. 2.

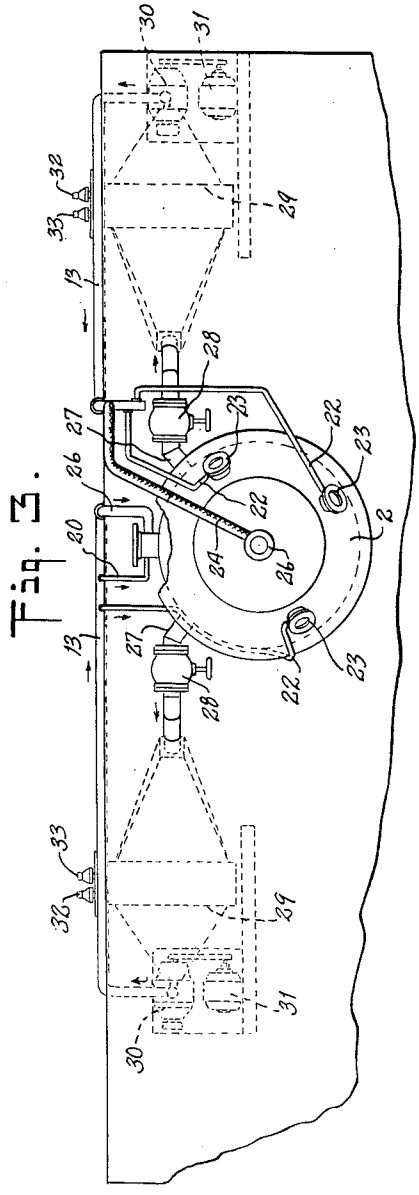


Fig. 3.

INVENTOR.
ROBERT J. GARMY
BY W. N. Woodruff
ATTORNEY

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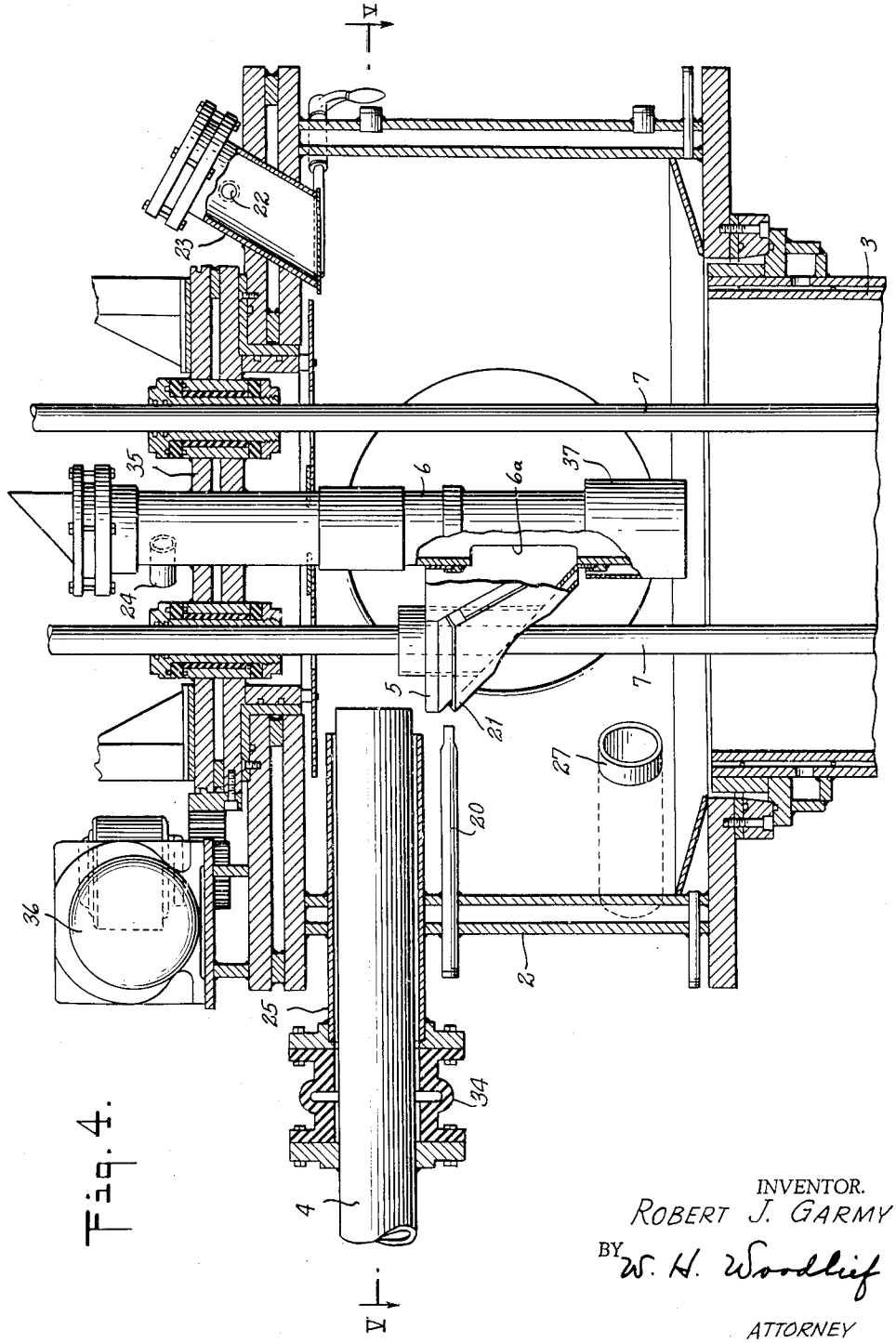


Fig. 4.

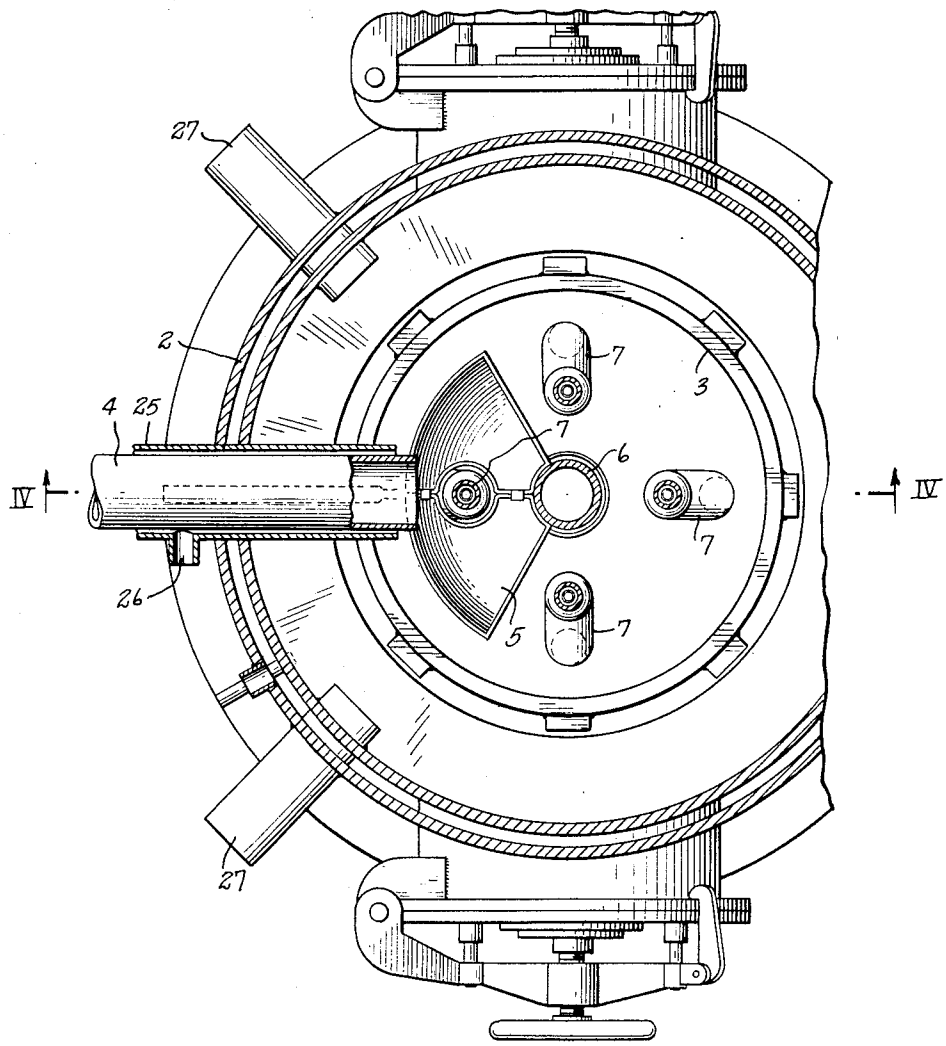
INVENTOR.
ROBERT J. GARMY
BY W. H. Woodliff
ATTORNEY

Sept. 13, 1960 R. J. GARMY 2,952,723

APPARATUS FOR CONTROLLING THE ATMOSPHERE IN AN ELECTRIC FURNACE

Filed July 10, 1957 4 Sheets-Sheet 4

Fig. 5.



INVENTOR.
ROBERT J. GARMY
BY W. H. Woodlief
ATTORNEY

United States Patent Office 2,952,723
Patented Sept. 13, 1960

2,952,723

APPARATUS FOR CONTROLLING THE ATMOSPHERE IN AN ELECTRIC FURNACE

Robert J. Garmy, Canton, Ohio, assignor to Republic Steel Corporation, Cleveland, Ohio, a corporation of New Jersey

Filed July 10, 1957, Ser. No. 670,921

4 Claims. (Cl. 13—33)

This application is a continuation-in-part of my copending application, Serial No. 391,549, filed November 12, 1953, entitled "Method and Apparatus for Forming Ingots," now Patent No. 2,800,519, dated July 23, 1957.

This invention relates to a method and apparatus for controlling the atmosphere in an electric furnace.

In order to obtain metal in a form which may be worked, i.e., rolled, forged, etc., in conventional fashion, it is first necessary to form a homogeneous ingot, usually by melting a quantity of the metal in a furnace. For products of the greatest purity, electric furnaces are preferred.

Metals are generally quite impure in the form in which they are first obtained by reduction from their ores. Titanium and zirconium, for example, are commonly obtained by reduction from their respective chlorides, with magnesium as the reducing agent. The resulting metal commonly contains magnesium chloride as an impurity. That material, and other common impurities, vaporize at the temperatures required in the melting furnace. These vaporized impurities interfere with normal furnace operation and tend to condense on and foul the cooler surfaces in the furnace structure where the melting operation is taking place. Furthermore, if these impurities are allowed to remain, they may contaminate the ingot, making objectionable flaws therein.

This invention is particularly concerned with controlling the atmosphere in such a furnace by maintaining it chemically inactive (i.e., of helium, argon, or the like), and by removing from the atmosphere impurities originating in the charge of material being treated, which impurities are volatile at the temperatures employed in the furnace.

The invention is of particular utility in the treatment of metals such as titanium and zirconium and their alloys. It is of more general utility in connection with the manufacture of ingots from other metals, e.g., steel, where a product of high purity is required.

An object of the present invention is to provide improved methods and apparatus for producing homogeneous ingots of metals such as titanium and zirconium.

Another object is to provide an improved electric furnace.

Another object is to provide improved apparatus for maintaining an inert gas atmosphere in an electric furnace during its operation.

Another object of the invention is to provide an improved method of controlling the pressure of an inert gas in a furnace for melting a metal such as titanium or zirconium.

Another object is to provide an improved method of circulating an inert gas through a space in which a metal such as titanium or zirconium is being melted.

A further object is to provide an improved method for removing impurities from such a metal by condensing vapors from the circulating inert gas.

These objects are attained by providing apparatus for circulating an inert gas, for example, helium, argon, or a mixture of both, through the furnace while it is operating. The inert gas leaving the furnace passes through a condenser where it is cooled so that the vapors and impurities picked up in the furnace are deposited in the condenser. The cooled gas is then returned to the furnace where it is used to cool vital parts and to displace contaminated gas.

Apparatus is provided for maintaining the pressure within the furnace within the range from about three to about five ounces per square inch above atmospheric pressure. This range is high enough to ensure that there are no air leaks into the furnace, while at the same time it is not high enough to cause absorption of the gas into the ingot, with resulting formation of flaws or other inhomogeneities therein.

Other objects and advantages of the invention will become apparent from a consideration of the following description and claims, together with the accompanying drawings.

In the drawings:

Fig. 1 is a somewhat diagrammatic illustration, partly in section and partly in elevation, of a furnace equipped with pressure control apparatus according to one feature of the invention;

Fig. 1*a* is a fragmentary view, similar to a portion of Fig. 1, showing a modification;

Fig. 2 is a somewhat diagrammatic elevational view of a furnace equipped with gas circulating apparatus according to another feature of the invention;

Fig. 3 is a plan view of the apparatus of Fig. 2;

Fig. 4 is a view, principally in section, on the line IV—IV of Fig. 5, and partly in elevation, with certain parts broken away, showing a furnace shell and gas inlets and outlets therefor; and

Fig. 5 is a fragmentary sectional view on the line V—V of Fig. 4.

The furnace illustrated herein is more completely described in my copending application Serial No. 391,549, now Patent No. 2,800,519, identified above. Only those parts of the furnace which are essential to an understanding of the present invention will be described in detail herein.

The furnace is generally indicated by the reference numeral **1**; it comprises a cylindrical shell **2**, open at the bottom, and a crucible **3**, also cylindrical, located below the open bottom of the shell **2**.

The metal to be melted to form an ingot is supplied in the form of particles or sponge from any suitable feeding mechanism into a feed pipe **4** (Figs. 4 and 5), which leads through a wall of the shell **2** and delivers the particles into a hopper **5** attached to a hollow central tube **6**. The hopper has an opening at its bottom aligned with an opening **6***a* in the tube. The tube is open at the bottom and the particles fall through it into the center of the crucible **3**, forming a pile **8** (Fig. 1).

A plurality of electrodes **7** (Fig. 1) extend downwardly into the crucible. A source of electrical energy (not shown) is connected to the electrodes **7** and to the walls of the crucible, and forms an arc between the electrodes and the charge in the crucible, thereby melting the particles to form a pool **9** of molten metal just below the electrodes. The crucible **3** is double-walled to provide cooling jackets, and the pool cools and solidifies to form an ingot **10**. The electrodes are raised as the material is fed in to maintain a more or less constant arc length between the electrodes and the pool surface.

Pressure regulating apparatus—Fig. 1

Fig. 1 illustrates apparatus for maintaining in the furnace **1** an atmosphere of inert gas at a regulated pressure. As there shown, the pressure regulating apparatus includes a resorvoir **11** which may represent a commercial cylinder of argon or helium gas, or a plurality of cylin-

ders providing a mixture of the two gases. The gas from the reservoir **11** flows through a constant pressure regulating valve **12** to one of the inlet pipes **13** described below in connection with Figs. 2 and 3. The pressure regulating valve **12** is controlled by the pressure in a static pressure line **14** connected to the interior of the furnace shell **2**. The arrangement is such that gas is admitted from the resorvoir **11** to the furnace shell **2** whenever the pressure in that shell drops below a predetermined value.

Excessive pressures in shell **2** are prevented by a controlled venting arrangement, including a vent pipe **15** leading from the interior of the shell **2** to a trap **16**. From the trap **16** a pipe **17** leads to a water bubbler pressure control mechanism **18**. The control mechanism **18** includes a container **19** mounted on a bracket **20** whose vertical position relative to the lower end of the pipe **17** may be adjusted by means of a suitable screw and slot arrangement **21**. The container **19** is provided with an overflow port **19***a* which determines the level of the water in the container. Water is continuously trickled into the container through a pipe **22**. The mechanism **18** maintains a fixed back pressure in the pipe **17**. The water supply pipe **22** maintains the level in the container **19** even though some of the water therein may be sucked back through the pipe **17** upon a sudden drop in pressure in the shell **2**. The trap **16** prevents any water which is sucked back in that manner from reaching the shell **2**.

A pressure in the range between three and five ounces per square inch above atmospheric pressure is employed. A pressure of at least three ounces per square inch is a safety precaution which eliminates all possibility of leakage of air into the furnace. Furthermore, the upper limit of this range is quite critical with regard to the quality of product. If a higher pressure is used, it has been found that gas occlusions occur in the ingot, which result in metallurgical defects in the finished product, namely scabs, slivers and laminations.

The equipment is adaptable with slight modifications shown in Fig. 1*a*, namely the addition of a vacuum pump **40** and elimination of the bubbler venting arrangement, to operation at pressures less than atmospheric, for purposes of reducing ingot hydrogen, for example. In such cases, the impurity (hydrogen) cannot be economically condensed or otherwise removed, and it is therefore in most cases not economical to recirculate the gas removed from the furnace.

Inert gas circulating system—Figs. 2 and 3

Figs. 2 and 3 illustrate, somewhat diagrammatically, a system for circulating an inert gas, for example helium, argon, or a mixture of the two, through the furnace shell **2** and thereby through the crucible during operation of the furnace.

It has been found that titanium which has been reduced from titanium tetrachloride by use of magnesium contains magnesium and magnesium chloride as impurities. When operating a furnace of the type described to form an ingot of titanium, these impurities vaporize at the high temperatures used for melting the titanium. If not removed from the furnace, these vapors adversely affect the stability of the arcs, and also tend to condense on the cooler parts of the furnace, thereby fouling those parts.

In accordance with the present invention, apparatus is provided for circulating inert gas through the furnace during its operation. In any operation involving titanium or zirconium, the gas must be one of the truly inert gases which cannot combine chemically with the titanium under any circumstances. Titanium, especially at high temperatures in the neighborhood of its melting point, is very active chemically and, with few exceptions, will combine with any element with which it is associated. Since helium and the other inert gases are quite expensive, it is desirable to recirculate the gas.

In the furnace shell **2** and its associated apparatus, there are provided a number of gas inlets, including a gas inlet pipe **20** (see Fig. 4) which directs cooled gas into a heat shield around the outside of the hopper **5**. Gas inlets **22** are provided in connection with three peripheral sight tubes **23** and a gas inlet **24** in connection with the center tube **6** which also serves as a sight tube. A heat shield tube **25** around the feed pipe **4** is also provided with a gas inlet **26** (Fig. 5).

All these gas inlets are shown in Figs. 2 and 3. There are also shown in Fig. 3 two gas outlets **27** from the furnace shell **1**. A dual gas circulating system is shown, the apparatus being duplicated for each outlet. Gas leaving either outlet **27** passes through a valve **28** and thence through a condenser **29**, a pump **30** driven by a motor **31** and thence through a discharge conduit or manifold **13** provided with branch conduits leading to the various gas inlets associated with the furnace shell **2**. Each half of the dual system serves one group of gas inlets to the shell **2**, and one of the two outlets **27**. It will be readily appreciated that a single system of sufficient capacity could be used in place of the dual system shown. The dual system was selected for the installation shown for reasons of convenience and economy and with regard to the space available.

Each condenser **29** has a water inlet **32** and a water outlet **33**. The condenser cooling coils are removable from the gas circulating system during periods of shutdown, in order to clean the deposits of magnesium and magnesium chloride from the cooling coils.

The inert gas circulating system serves to remove impurities such as magnesium and magnesium chloride and prevent their inclusion in the finished ingot. Furthermore, when the gas circulating system is operated at a pressure greater than atmospheric, the inert gas prevents oxygen, nitrogen and other chemically active constituents of the atmosphere from coming in contact with the molten titanium, which might otherwise become contaminated with such constituents.

Although the gas pressure regulating system of Fig. 1 is not shown in Figs. 2 and 3, it should be understood that a complete system would preferably include both the pressure regulating system of Fig. 1 and the gas circulating system of Figs. 2 and 3.

Details of shell—Figs. 4 and 5

The titanium sponge is fed to the furnace in a continuous stream, preferably from a vibratory feeder (not shown) of any suitable commercial type. The feeder discharges through the feed pipe **4** (see Fig. 4). The feed pipe **4** extends through the shield pipe **25** which is mounted in the side wall of the furnace shell **1**. A flexible coupling **34** connects the feed pipe **4** with the stationary shield pipe **25**.

The electrodes **7** extend into the furnace through a head **35** which may be oscillated by means of a motor **36**. At the center of the head **35** the tube **6** projects downward inside the shell **2**. Supported on the outside of the post **6** is the hopper **5**. The hopper **5** is generally sector shaped in its horizontal cross-section, as may be seen in Fig. 5. Its upper end extends radially out from the hollow post far enough so that its periphery is below the inner end of the feed pipe **4**.

As shown in Fig. 5, one of the electrodes **7** extends vertically downward through the hopper **5**. In order to permit this, the hopper is made in right and left-hand sections, each with a recessed face which together define a sleeve to permit free passage of the electrode **7**.

The heat shield **21** (Fig. 4) generally conforms to the shape of the hopper and is spaced from it by a short distance. The nozzle **20** projects through the side of the shell **1** and terminates at a point directly opposite the opening between the upper end of hopper **5** and heat shield **21**. As described above, the nozzle **20** receives a continuous supply of cooled inert gas, for example, helium, which is directed into the space between the heat shield and the hopper and passes downwardly through

that space and out the lower end thereof. A collar **37** is mounted on the lower end of the tube **6** and is concentric with the tube and spaced outwardly from it. The upper end of the space between tube **6** and collar **37** is directly opposite the lower end of the space between heat shield **21** and hopper **5** so that the flow of cool gas passing through that space tends to continue through the space around the lower end of the tube **6**. It may therefore be seen that all the parts through which the titanium sponge passes on its way to the center of the crucible are cooled by gas jackets and shields. These parts include the feed pipe **4** cooled by the gas flowing through shield pipe **25**, the hopper **5** cooled by gas flowing through the shield **21** and the lower end of the tube **6** cooled by gas flowing through the shield **37**. The shields are also effective in reducing radiated heat. This cooling action prevents the metal particles from becoming tacky and clogging the feed mechanism.

The cooled gas entering the various inlets tends to move by convection downward toward the locality of the arc in the crucible, whereas the gas heated by the arc and the vaporized impurities tend to move upward, also by convection. There is thus maintained in the crucible a flowing current of gas tending to carry the impurities away from the arc and the forming ingot.

Cooled gas entering the inlets **22** maintains a flow through each sight tube in a direction away from the glass, thereby preventing fogging of the glass by condensation of vaporous impurities from the furnace.

By feeding the material through the side of the shell **2**, interference with the oscillating head **35** and other mechanism (not shown) on and above the head is avoided.

I claim:

1. An electric furnace comprising a generally cylindrical shell, means for feeding material to be treated in the furnace to a central locality thereof, said feeding means comprising a hopper within said shell, a heat shield generally conforming to the outer wall of the hopper and spaced outwardly therefrom to provide an open space between said outer wall and the heat shield, a condenser spaced from said shell for cooling a gas flowing therethrough, means for circulating an inert gas through the shell and the condenser to pick up vaporous impurities in the shell and remove them by condensation in the condenser, and means for recirculating cooled gas from the condenser back to the shell, said recirculating means comprising means for directing a flow of cooling gas into said open space.

2. An electric furnace as defined in claim 1, in which said feeding means comprises a hollow center post projecting downwardly within said shell and open at its lower end, and said recirculating means comprises means for directing a flow of cooling gas downwardly through said hollow center post.

3. An electric furnace comprising a generally cylindrical shell, means for feeding material to be treated in the furnace to a central locality thereof, said feeding means comprising a hollow center post projecting downwardly within said shell and open at its lower end, a feed pipe extending through a side of the shell and having its inner end open and spaced from the center post, a heat shield tube encircling the feed pipe and open at its inner end, a hopper mounted on the center post and having an upper peripheral portion underlying the inner end of the feed pipe, said hopper and post having aligned openings and providing a path for the material from the feed pipe through the hopper and into the center of the hollow post, a heat shield generally conforming to the outer wall of the hopper and spaced outwardly therefrom to provide an open space between the outer wall and the heat shield, a condenser spaced from said shell for cooling a gas flowing therethrough, means for circulating an inert gas through the shell and the condenser to pick up vaporous impurities in the shell and remove them by condensation in the condenser, and means for recirculating cooled gas from the condenser back to the shell, said recirculating means comprising means for directing flows of cooling gas into said open space, into the space between the heat shield tube and the feed pipe, and into said hollow post.

4. An electric furnace as defined in claim 3, including a collar encircling the lower end of the hollow post and cooperating therewith to define an annular passage, said passage having its upper end open and adjacent said open space to receive a current of cooling gas therefrom.

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