Feb. 13, 1951 S. A. HERRES ET AL 2,541,764

ELECTRIC APPARATUS FOR MELTING REFRACTORY METALS

Filed April 15, 1948 2 Sheets-Sheet 1

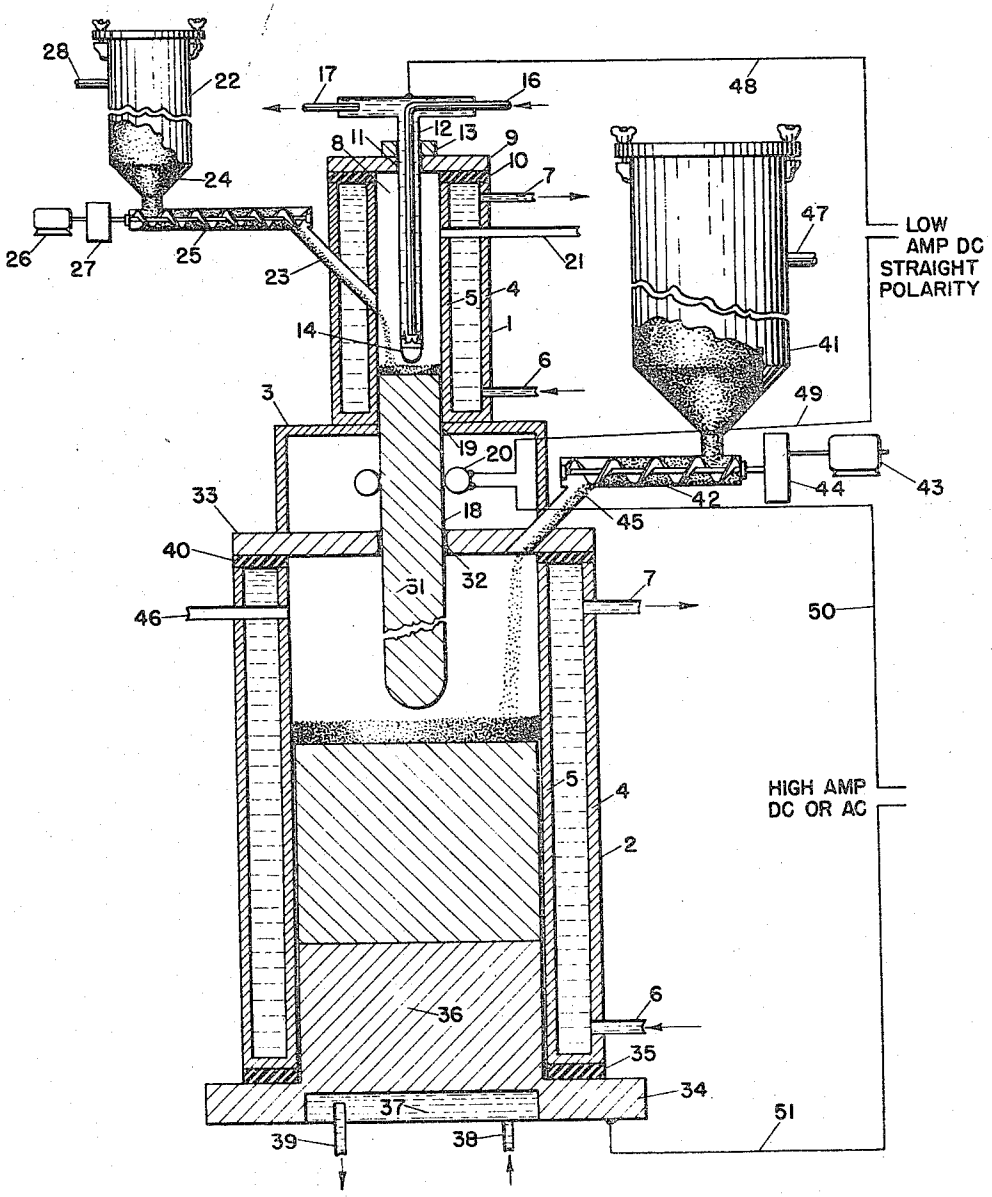


FIGURE 1

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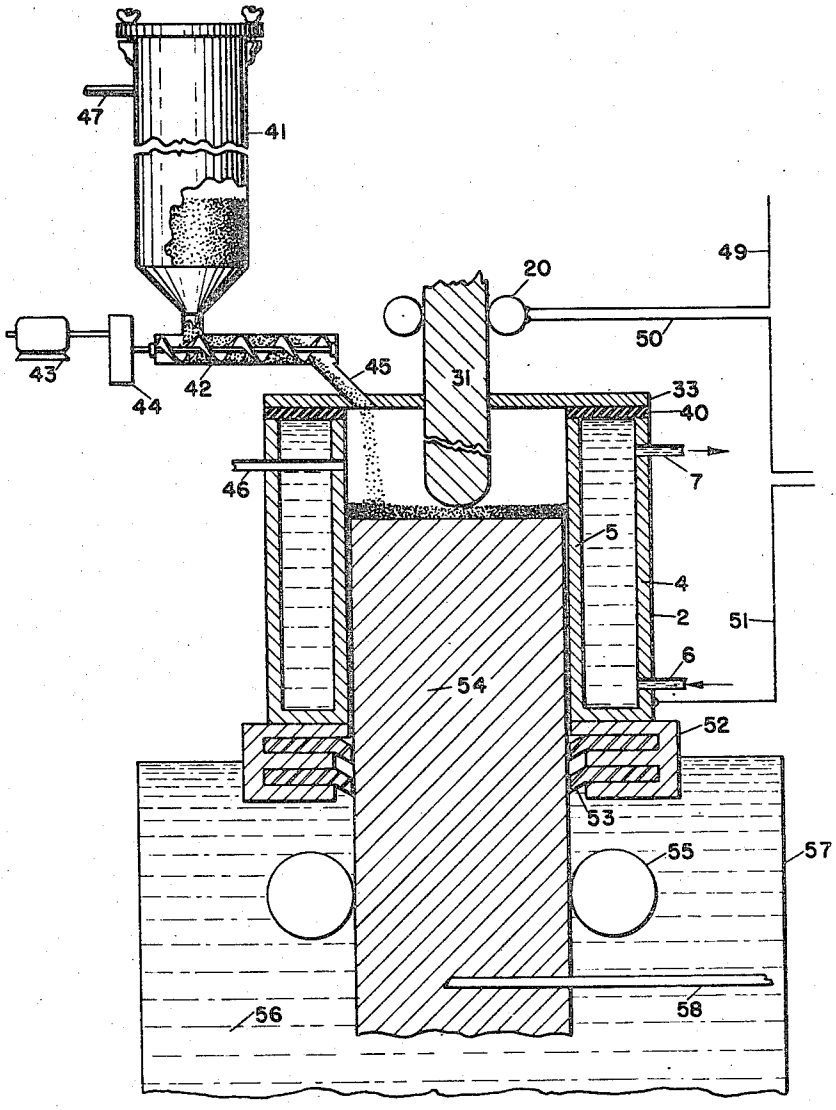


FIGURE 2

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ELECTRIC APPARATUS FOR MELTING REFRACTORY METALS

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2 Claims. (Cl. 13—9)

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This invention pertains to method and apparatus for melting refractory metal, and more particularly to a method and apparatus for reducing powdered metals to ingot or casting form in which the melting and casting are performed concurrently. "Powdered metal" as used herein is to be construed to mean metal in size increments which are substantially less than the size of the ingot or casting to be formed.

The melting point of metals such as titanium, zirconium, chromium, molybdenum, and tungsten, or metals having like or similar characteristics, as well as the carbides, oxides and other compounds of such metals, is so high that melting thereof in conventional refractory crucible type furnaces is extremely difficult and generally unsatisfactory because of the tendency of the metals to react with the ceramic and contaminate the metal. Likewise, handling of metals at temperatures of approximately 2000° C. when such metals are melted in the conventional crucible type of furnace presents problems which practically precludes use of such conventional crucible method.

In accordance with this invention a method and an apparatus is provided which will not only permit the successful formation of ingots or castings without the disadvantages attendant to the use of the conventional crucible methods but will also permit continuous formation of an ingot or casting of such refractory metals as aforementioned in any desired size whereby ingots or castings for either small or large finished parts may be had.

In accomplishing this invention there is provided a pair of counterelectrodes, one of which electrodes is in the form of a container adapted to receive the refractory metal in powdered form and to determine the shape and size of the ingot or casting. The other electrode of the pair is a permanent electrode as distinguished from a consumable electrode. The ingot or casting formed by the pair of electrodes just described forms the consumable electrode of another pair of counterelectrodes, the other of such pair of electrodes being formed by a second and enlarged container for receiving the refractory metal in powdered form. Thus, there is provided an apparatus for forming ingots or castings from powdered refractory metal in which the electrode utilized in forming the ultimate ingot or casting is of the consumable type but such electrode is constantly renewed by addition to one end thereof at a rate substantially like the rate at which the electrode is being consumed at its opposite end, and provision for the making of ingots or castings of

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large volume is provided for. As will be hereinafter described, this invention also makes possible the formation of ingots or castings from refractory metals in a continuous manner.

Various objects and advantageous features of the invention may be had from the following description, and one embodiment thereof may be seen in the accompanying drawings wherein similar characters of reference designate corresponding parts, and wherein:

Figure 1 is a view, partly in section and partly in elevation, showing an apparatus embodying the ideas disclosed by this invention.

Figure 2 is a fragmentary view, partly in elevation and partly in section, showing a modified form of the invention.

Referring to Figure 1 of the drawings, there is shown one embodiment of the invention in the form of melting furnace which includes two forms or containers 1 and 2, disposed one above the other and maintained in spaced relation by a frame or casting 3. Each of the forms or containers 1 and 2 are made up of spaced walls 4 and 5 providing a reservoir therebetween for receiving water which may be introduced through water inlets 6 and withdrawn through water outlets 7. Any suitable means may be used for circulating the water through the reservoirs formed by the spaced walls 4 and 5. The wall 5 may be of any material having a high heat conductivity and a moderately high melting point, for example, copper, and the outer wall 4 may be of any suitable material which will provide the wall of a liquid reservoir.

The uppermost form or container 1 rests upon and is secured to the frame or casting 3, and the tubular chamber 8 formed by the walls 5 is closed at its top by a cap 9 held separated from the walls 4 and 5 by a gasket 10 of suitable insulating material and is preferably removably secured to the uppermost ends of the walls 4 and 5 in any suitable manner. Such cap 9 has a central opening 11 through which an electrode 12 extends downwardly into the chamber 8. Such electrode 12 is rotatably and longitudinally movable in the opening 11 and through a sealing ring 13 the purpose of which will be hereinafter apparent.

The electrode 12 consists of a hollow stem of, for example, steel having brazed to the free end thereof a welding tip 14 of some high melting point material, for example, tungsten. Leading into the upper end of the hollow stem 12 and extending substantially throughout the length of the stem to a point adjacent the tip 14 is a water inlet pipe 16 through which water may be in-

troduced into the interior of the electrode stem and be discharged on the upper surface of the tip 14, and a water outlet 17 is provided at the top of the electrode stem whereby the water introduced into the stem adjacent the bottom thereof will flow along the walls of the stem in its passage outwardly and cool the stem.

The tip in the present instance is of tungsten inasmuch as tungsten has a high melting point and since the heat necessary is approximately 2000° C., the heat generated in the tungsten by the resistance and heat of the arc is obviously high; and in order to have a permanent rather than a consumable tip, the length and diameter of the tip has such relation to the area of the topside of the tip which is contacted by the water flowing through the pipe on the stem of the electrode that the amount of heat dissipated from the tip with respect to the heat input will be in substantial equilibrium within a range of temperatures, the highest of which is less than the melting point of the tip. Such equilibrium is likewise controlled by the temperature of the water and the rate of flow and impingement of the water on the upper surface of the tip. It follows that the tips may be of varying size, but that there should be such relation between the size and the tip, the area of the tip on which the cold water impinges, the rate of flow of the water, and the temperature of the water, that the equilibrium hereinbefore set forth will be maintained.

The outer surface of the tip is ground after the tip is brazed to the stem and the electrode is movable vertically and also rotatable about its longitudinal axis. If desired, the end of the stem adjacent the powdered metal may be bent to offset the tip from the axis rotation of the electrode whereby rotation of the electrode will cause the tip to move in a circular path and be directly effective over the greater area of the powdered metal. Likewise, if desired, a plurality of electrodes may be used in a single container.

The bottom of the uppermost form or container is unrestricted except for the ingot or casting 18 being formed, and which ingot or casting extends downwardly through an opening 19 in the frame or casting 3 wherein are disposed spaced rollers 20 which engage around the outer periphery of the ingot or casting 18 to support the ingot or casting and provide a means for moving such ingots or castings in the direction of their longitudinal axis.

A conduit 21 leads to the interior of the chamber formed by the walls 4 and 5 of the upper form of container and provides a means for introducing inert gases into the chamber or producing a vacuum in the chamber, as may be desired. In order to supply powdered metals to the chamber formed by the walls 5 a hopper 22 is provided which has a conduit 23 leading to the chambers, and powdered metal 24 from such hopper may be introduced into the chamber continuously as by means of the screw-type feed including a screw 25 driven by a motor 26 through suitable reduction gearing 27, or the feed of powder may be intermittent and controlled by a suitable hand-operated valve if desired. Suitable means such as a pipe 28 may be provided for introducing inert gases into the hopper 22 or producing a vacuum therein so that the interior of the entire apparatus may be under the same conditions.

Referring to Figure 1 of the drawings it will be seen that the ingot 31 formed as hereinbefore

described in the uppermost form or container extends downwardly through an opening 32 in the cap 33 of a lower form of container made up of spaced walls 4 and 5 which form a water reservoir having a water inlet 6 and a water outlet 7, and which lower form or container 2 is of substantially greater size than the upper form or container 1. This lower form or container 2 is provided with a base 34 which may be secured to the lower end of the walls 4 and 5 in any well-known manner which will permit the base to be removed, and a sealing gasket 35 is provided between the base and the end of the walls 4 and 5. Such base is formed with an upwardly extending portion 36 of a diameter to fit within the chamber formed by the inner wall 5 and is provided immediately below or beneath the portion 36 with the cavity or reservoir 37 having a water inlet 38 and a water outlet 39 for the circulation of water through the cavity 37 to cool the base. A ring 40 of insulating material is positioned between the upper end of the walls 4 and 5 and the cap 33.

Powdered metal may be fed to the lower form or container similarly to the manner in which powdered metal is fed to the upper form of container, for example, by way of a hopper 41 and a screw 42 driven by a motor 43 through a reduction gearing 44 through an inlet 45 leading to a lower form or container. Likewise, an atmosphere of inert gases such as argon or helium, or a vacuum may be produced within the lower form or container and the hopper 41 by way of suitable conduits 46 and 47.

In utilizing this apparatus to melt high refractory metals of the type herein mentioned or the carbides, oxides, and other compounds thereof, for the purpose of producing ingots or castings, water is first introduced and circulated through the confined spaces between the walls of the containers to provide container walls of such temperatures that the melting powder adjacent the container walls will cool so quickly the metal will not stick or adhere to the walls, and to maintain the temperature of the container walls and the bottom of the lower container of such degree that the material of the walls will not be affected by heat in a manner to produce contamination of the powdered metal being melted, or pin-holing of the ingot or casting surface. Water is likewise introduced and caused to flow through the electrode 12 to cool the length of the electrode beyond the tip and to maintain the tip itself at less than melting temperatures of the metal forming the tip thereby it is possible to have other than a consumable electrode.

It is preferable that the melting of the powdered metal take place in an atmosphere filled with inert gas such, for example, as argon or helium, or in a vacuum, and such inert gases are introduced into the container and the hopper, or a vacuum is created in the container and the hopper, by suitable means through the medium of conduits 21 and 28, 46 and 47. If inert gases are provided, it is preferable that the containers and the hoppers be filled with inert gas and a slight positive pressure of such gas maintained therein.

Assuming that an ingot or a portion of an ingot is positioned as shown in Figure 1, powdered metal is fed from the hopper 22 to the top of the ingot, and the electrode having been positioned properly with relation to the powdered metal, the proper arcing will be had to melt the powdered metal. In practice, the bottom ex-

tremity of the tip 14 is disposed ordinarily from ½- to ¾-inch from the powdered metal. As the powdered metal is melted by the increase in temperature, additional powdered metal is either fed to the container continuously or in increments of predetermined amount and the ingot is moved downwardly in order to maintain the proper distance between the tip and the powdered metal.

The size of the ingots or castings which can be produced is dependent upon the size of the container or form, the amount of power available and other well-known factors. The current setting should be set as to insure complete melting of the powdered metal from the inside surface of the container inwardly toward the center thereof, and the rate of melting of the powdered metal may be varied by varying the character and amount of electric current supplied. For example, it has been found that in forming an ingot or casting of approximately 1¼-inch in diameter, a rate of melting of from about ¼" inch to 1" inch per minute may be obtained depending upon the rate of feed of powdered metal and current setting.

It being understood that the electrode 12 and tip 14 is adjustable vertically, and the ingot 31 which forms the lower one of the upper pair of counterelectrodes as well as the upper one of the lower pair of counterelectrodes is also adjustable vertically through operation of the rollers 20, the electrode 12 and ingot 31 are initially moved to up-position and the electrical circuits for producing arcing between the electrodes are energized. For the upper pair of counterelectrodes the circuit includes a line 48 leading to the electrode 12 having the tip 14 and a line 49 leading to one of the rollers 20 supporting the ingot 31. It is preferable to use a relatively low amperage D. C. straight polarity current and thus keep the side represented by the electrode 12 and tip 14 coolest, since keeping such side coldest is desirable in the utilization of a permanent electrode and there is less likelihood of the temperature being such as to melt the tip. For the lower pair of counterelectrodes the line 50 leads to one of the rollers 20 supporting the ingot 31 and a line 51 leads to the base 34 or the side walls of the lower form or container as the case may be. The current in this circuit is preferably high amperage A. C. or D. C. current.

With the electrode 12 and ingot 31 in up-position, powdered metal is fed to the lower form or container from the hopper 41 in an amount, first, to cover the bottom of the container, and secondly, in an amount sufficient that the arc will start on the powdered metal instead of on the base or side walls of the container. The ingot 31 is then moved downwardly until the lowermost end or tip thereof is in such position that the proper arcing will be had between the lower end or tip and the powdered metal. As the powdered metal is melted by the increase in temperatures, additional powdered metal is either fed to the container continuously or in increments of predetermined amount and the lowermost end or tip of the ingot 31 is maintained in the proper spaced relation with the powdered metal being melted by adjusting the position of the lowermost end or tip of the ingot in accordance with the increase in depth of the ingot being formed and/or the melting away of the tip of the ingot 31.

With respect to the uppermost end of the ingot 31 and addition thereto by melting powdered metal in the uppermost form or container, powdered metal is either supplied to the uppermost form or container continuously from the hopper 22 or in increments thereof and the electrode 12 is moved downwardly until the tip 14 is in such position that the proper arcing will be had between the tip 14 and the powdered metal supplied to the uppermost end of the ingot 31. As the powdered metal is melted by the increase in temperature, additional powdered metal is either fed to the container continuously or in increments of predetermined amount and the electrodes 12 and tip 14 is moved either downwardly or upwardly in order to maintain the proper distance between the tip and the powdered metal as determined by the building up and increase in length of the ingot 31, or the position of the upper end of the ingot is determined by adjustments of the ingot 31 vertically to maintain the proper spaced relationship between the lowermost end or tip thereof and the powdered metal being melted in the lower form or container to thereby form an ingot on the base 34. It will be seen that with both the electrodes 12 and the ingot 31 adjustable vertically the proper spaced relation can be maintained between the lowermost end or tip of the ingot 31 which is consumable and the tip 14 of the electrode 12 which is permanent and the powdered metal being melted thereby. If desirable, the uppermost end of the ingot may be added to by intermittent rather than continuous operation of the upper pair of electrodes.

Referring to Figure 2 of the drawings, the apparatus is shown as being arranged for the continuous production of casting or ingot. The lowermost container 2 made up of the walls 4 and 5 rather than having a removable bottom has a metal housing 52 secured thereto in any desired well-known manner, such metal housing being arranged to receive two annular flexible sealing rings 53 of suitable material in a manner such that the inner circumferences of the sea'ing rings will engage the outer circumference of the ingot or casting 54. The inside diameters of the rings are less than the diameter of the ingot or casting 54 whereby the rings will engage the ingot tightly as shown and permit an atmosphere of inert gas or a vacuum to be maintained in the lowermost melting container.

Rollers 55 are provided for guiding the ingot downwardly into a bath of liquid such as oil or water 56 in a tank 57, and a suitable cutoff means such as the diagrammatical'y illustrated flying saw 58 may be provided to cut the ingot into suitable lengths. There should be such distance between the top of the ingot where the powdered metal is melted and the bottom of the container so that the ingot may cool sufficiently as not to adhere to the sealing rings 53 or the sealing rings themselves may be of such material as not to adhere to the outer circumference of the ingot.

With the invention herein disclosed there is provided a method and apparatus for producing castings or ingots of comparatively large volume and diameter either intermittently or continuously. There is also provided the novel arrangement of a permanent and a consumable electrode and wherein the consumable electrode is continuously or intermittently increased in length at one end while being reduced in length at its opposite end. It is to be understood that the uppermost permanent e'ectrode may be arranged in multiple in order to produce multiple consum-

able electrodes, and which latter electrodes may be arranged in multiple with respect to the lowermost form or container if such arrangement is found to be desirable in order to produce an ingot or casting of comparatively large diameter and body.

What is claimed is:

1. Apparatus for producing ingots from powdered refractory meta's of the group consisting of titanium and zirconium, comprising a container, a permanent electrode extending downwardly into said container, means for supplying powdered refractory metal to said container, an ingot of the said refractory metal forming the bottom of said container and extending downwardly therebelow, said ingot forming the other electrode of a pair of counterelectrodes including the said permanent electrode, means for supporting said ingot and moving said ingot downwardly relative to said container as the powdered refractory metal is melted by the arc between the two said e'ectrodes to increase the length of said ingot, means for cooling said molten powdered refractory metal as the said ingot supporting it moves downwardly and thereby solidifying such molten metal as a continuation of said ingot, a second container into which the lower end of said ingot extends, means for supplying powdered refractory metal to said second container, said second container having a bottom forming one of a pair of counterelectrodes, the other of said last-named pair of counterelectrodes being formed by said ingot extending from the first-named container into said second-named container, and which ingot forms a consumable electrode to, by the melting effect of the arc and with the powdered refractory metal supplied to said second container, form an ingot of greater dimensions than said first-named formed ingot in the second container.

2. Apparatus for producing ingots from powdered refractory metals of the group consisting of titanium and zirconium, comprising a container, a permanent electrode extending downwardly into said container, means for supplying powdered refractory metal to said container, an ingot of the said refractory metal forming the bottom of said container and extending downwardly therebelow, said ingot forming the other electrode of a pair of counterelectrodes including the said permanent electrode, means for supporting said ingot and moving said ingot downwardly relative to said container as the powdered refractory metal is melted by the arc between the two said electrodes to increase the length of said ingot, means for cooling said molten powdered refractory metal as the said ingot supporting it moves downwardly and thereby solidifying such molten metal as a continuation of said ingot, a second container into which the lower end of said ingot extends, means for supplying powdered refractory metal to said second container, said second container having a bottom forming one of a pair of counterelectrodes, the other of said last-named pair of counterelectrodes being formed by said ingot extending from the first-named container into said second-named container, and which ingot forms a consumable electrode to, by the melting effect of the arc and with the powdered refractory metal supplied to said second container, form an ingot of greater dimensions than said first-named formed ingot in the second container, the said last-named ingot extending downwardly from the said second container, means for supporting said last-named ingot and moving said ingot downwardly out of the second container as the length thereof is increased by addition to the upper end thereof.

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