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APPARATUS AND METHOD OF CONTINUOUSLY CASTING METAL INGOTS

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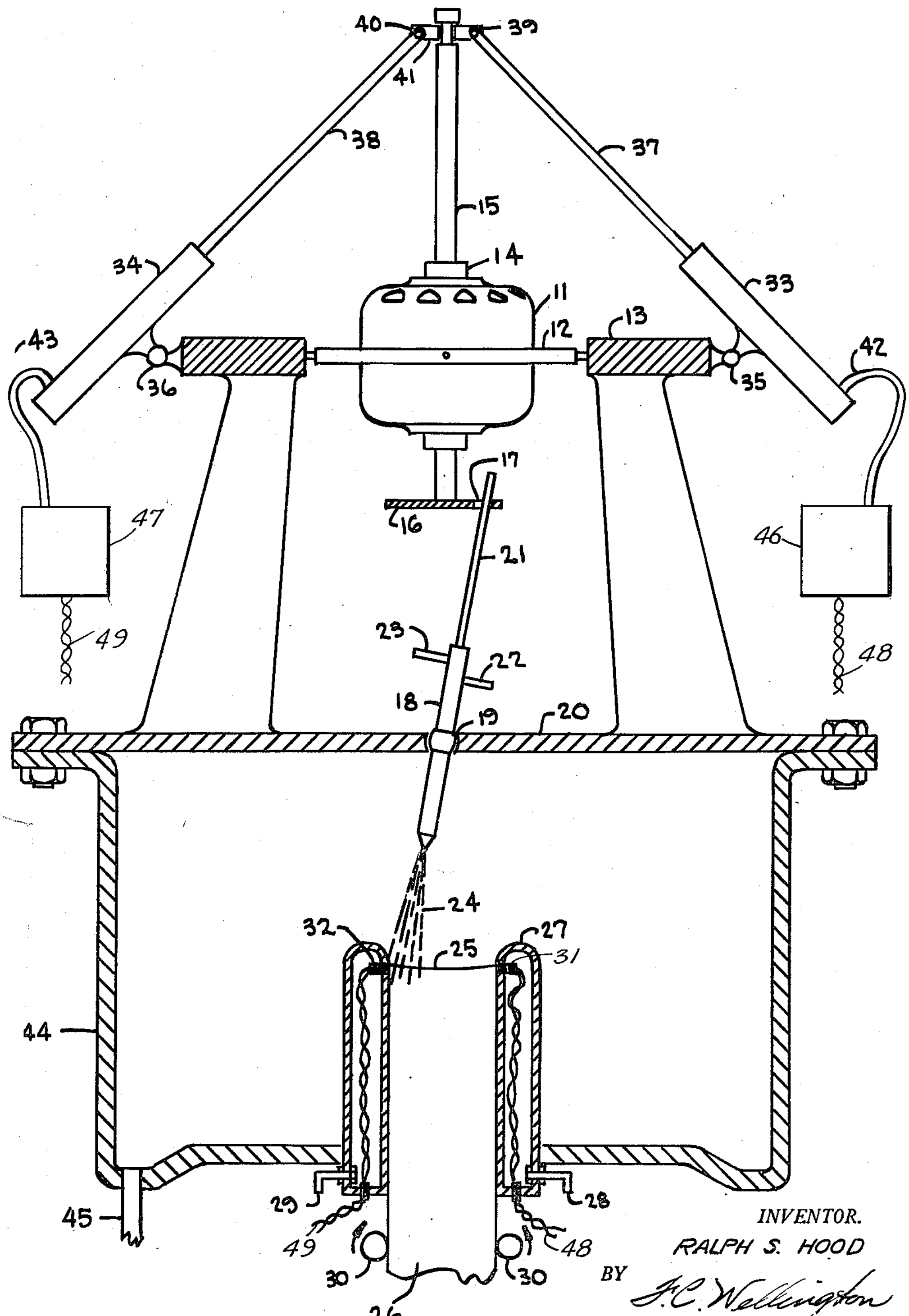

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APPARATUS AND METHOD OF CONTINUOUSLY CASTING METAL INGOTS

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3 Claims. (Cl. 22—57.2)

This invention relates to the casting of metal and especially to continuous casting of ingots of high melting point metals, such as titanium, zirconium, etc. The invention also relates to an apparatus for carrying out the above continuous casting procedure.

Briefly stated, the invention comprises an improvement in ingot casting whereby the molten metal is deposited upon the ingot symmetrically about the longitudinal axis of the ingot by moving the point of deposition of molten metal in a circular motion in a plane at right angles to the longitudinal axis of the ingot. The temperature of the periphery of the ingot is measured to give an indication of the temperature distribution across the surface of the ingot and at the same time an indication of the uniformity of distribution of molten metal on the surface of the ingot. The center of the above circular motion (of the point of deposition of molten metal) is then moved in response to these temperature determinations so that the metal is deposited more uniformly on the surface of the ingot.

The present invention is particularly useful when used in conjunction with the invention disclosed and claimed in the copending patent application of Findlay, Serial No. 200,606, filed December 13, 1950. According to the Findlay invention a gaseous stream of a halide of titanium (e. g., titanium tetrachloride) and a gaseous stream of a reducing metal, such as an alkali or alkaline earth metal (e. g., sodium or calcium) or magnesium, are directed through a nozzle or torch and mixed to form a flame in which the titanium halide and reducing metal react to form molten metallic titanium and gaseous reducing metal halide. The nozzle or torch is directed toward a target upon which the molten titanium is deposited and solidified, thereby building up a mass of solid metallic titanium. As the titanium solidifies, it is slowly drawn from the reaction chamber as a cylindrical ingot, thereby maintaining the surface upon which the titanium is deposited at a constant distance from the torch nozzle.

In the Findlay process it is highly desirable that the metal be deposited uniformly upon the surface of the titanium ingot. If, however, some imperfection or obstruction in the reaction torch causes the flame to be diverted away even slightly from the direction in which the torch is pointed, the metallic titanium will be deposited more heavily upon one side of the ingot than upon the other side and may result in a faulty ingot. This type of difficulty may be readily avoided by the process and apparatus of the present invention.

The present invention may be more clearly understood by reference to the drawing, which illustrates a specific embodiment of the broader invention.

A motor 11 is mounted in gimbals 12 in a frame 13 so that shaft 14 of the motor can be freely tilted in any direction away from the vertical. A smaller shaft 15 extends through the motor shaft 14. The smaller shaft is keyed to the motor shaft so that the smaller shaft rotates with the motor shaft but is free to move through the motor shaft along the longitudinal axis of the shafts. On the lower end of the smaller shaft is a circular disc 16 containing an eccentrically placed hole 17. A reaction torch 18 is mounted with a universal joint 19 in the cover 20 of the reaction chamber 44. The reaction torch has attached thereto a rod 21 extending upward and through the eccentrically placed hole 17 in the disc 16. The reaction gases, such as titanium tetrachloride and sodium, enter the torch through the lines 22 and 23, respectively, and react to form the flame 24 which is directed upon the surface 25 of the ingot 26 which is formed within the ingot mold 27. The ingot mold is hollow to allow for fluid cooling through the lines 28 and 29. Cooling the ingot causes the molten titanium deposited upon the surface of the ingot to solidify and become a part of the solid metal ingot. The ingot is continuously withdrawn from the ingot mold by means of the rollers 30. Thermocouples 31 and 32 are set into the inner wall of the ingot wall, adjacent to the ingot.

Hydraulic cylinders 33 and 34 mounted upon the frame 13 by universal joints 35 and 36 are connected by piston rods 37 and 38 and pins 39 and 40 to a collar 41 which rotates freely upon shaft 15 but is restricted from moving longitudinally along said shaft. The hydraulic cylinders 33 and 34 are actuated by temperature responsive power sources 46 and 47 which transmit power through lines 42 and 43 in response to the temperature indications received from the thermocouples 31 and 32, respectively, by way of thermocouple leads 48 and 49, respectively.

When the motor 11 operates in a vertical position, the rotation of the disc 16 causes the torch to rotate and the reaction flame to describe a circular motion upon the ingot surface 25, thereby depositing metallic titanium upon the ingot symmetrically about the longitudinal axis of the ingot.

If, however, some sort of an obstruction in the nozzle causes torch flame 24 to be deflected as it emerges from the nozzle tip, then the metal will not be deposited symmetrically upon the surface of the ingot.

Assuming a situation where an obstruction might cause the flame to be deflected to the left as it emerges from the nozzle, it may be seen that this will cause a higher concentration of metal to be deposited upon the left side of the ingot than upon the right side of the ingot. As the molten metal solidifies, the latent heat of fusion released by the greater mass of metal deposited on the left side of the ingot will result in a higher temperature on the left side of the ingot. This higher temperature will be noted by the thermocouple 32 and the information relayed to the temperature responsive power source furnishing power to the cylinder 34 through the line 43 so that the plunger 38 will be further extended, thereby causing the upper end of the rotating shaft 15 to be deflected to the right of the vertical. As a result of this deflection the center of rotation of the nozzle tip will move to the right of center line of the ingot 26 to a point at which the deposition of metal will cause the temperatures indicated by the thermocouples 31 and 32 to be equal.

If the obstruction which caused the above-described shift in torch movement to take place is later removed, then an action opposite to that described above will take place and cause the torch rotation to revert to its original state whereby the motor shaft 15 will again be in a vertical position.

The temperature responsive actuating means (which operate the hydraulic cylinders in response to the temperature indications from the thermocouples) may be any one of numerous control devices such as are commercially available for this type of operation. An example of a suitable control means is the "Continuous Balance Potentiometer" unit and "Air-o-Line Control" unit manufactured by Brown Instrument Company (Minneapolis-Honeywell Regulator Company) as described in their bulletin 15–4R, June, 1951.

The drawing, and the foregoing explanation thereof, illustrate temperature measurements (and control in response thereto) only in a single plane (i. e., the plane of the drawing). In actual operation it will be generally desirable to provide an equal degree of control in a plane perpendicular to the plane of the drawing. This can be done by a duplicate set of thermocouples and control devices operating simultaneously with the one described above but in a plane at right angles thereto. It can also be done with three thermocouples and corresponding control units equally spaced 120° apart around the periphery of the ingot and the apparatus.

It should also be noted that in the specific embodiment illustrated in the drawing, if the temperatures indicated by thermocouples **31** and **32** go above or below some pre-determined level (even though the temperatures at points **31** and **32** are equal to each other) the shaft **15** will be raised or lowered to decrease or increase the diameter of the circle inscribed by the torch flame **24** upon the surface **25**. This serves as an additional means of controlling the temperature distribution across the surface of the ingot.

The foregoing description has been generally limited to the specific embodiment shown in the attached drawing. It is apparent, however, that there are many variations which will be equally effective in carrying out the present invention. For example, under some circumstances it might be necessary or desirable to vary only the diameter of the circle inscribed by the torch flame. This could be accomplished by permanently mounting the motor in a vertical position so that the shaft **15** would be free to move only up and down through the motor shaft **14** but could not be deflected away from the vertical. In such a case only one hydraulic cylinder unit would be required to control the mechanism.

On the other hand, it might be desirable to be able to displace the center of rotation of the nozzle or torch but not necessary to change the diameter of the circle inscribed by the torch. This could be accomplished by making the motor shaft **14** and the sliding shaft **15** as one shaft, thereby eliminating the possibility of vertical motion of the disc **16**, but still allowing the shaft to be diverted from the vertical by having the motor mounted in gimbals. In such a case only two hydraulic control systems would be necessary, these operating at right angles to each other in a horizontal plane perpendicular to the longitudinal axis of the ingot.

As another variation the nozzle might be positioned and actuated so that the rotation of the torch generated a cylinder rather than a cone.

It will also be apparent that the pairs of thermocouples mounted on opposite sides of the ingot may be utilized to indicate temperatures independently of each other or the thermocouples on opposite sides of the ingot may be interconnected in one circuit to indicate only a temperature differential between the opposite sides of the ingot.

While the specific embodiment of the invention described above has utilized hydraulic power as the means of varying and controlling the torch motion, pneumatic, electrical or simple mechanical means can also be used. It should also be understood that the present invention is not limited to the deposition of metals deposited from a chemical reaction such as described above, but that it is also applicable to other methods of continuously depositing molten metal upon an ingot, such as in the continuous casting of titanium ingots by the re-melting of titanium sponge or powder with an electric arc.

What I claim is:

1. Apparatus comprising a nozzle adapted to direct a reaction stream of gaseous titanium halides and gaseous reducing metals in a pre-determined direction, means for uniformly rotating said nozzle in a manner such that the directed reaction stream describes a curved surface, a plurality of temperature indicating means adapted to indicate the temperature distribution about the periphery of the surface of the metallic titanium deposited from said reaction stream, and means for moving the center of rotation of said nozzle in response to said temperature indications.

2. In a method of continuously casting a metal ingot by depositing molten metal on one end thereof, the improvement comprising depositing said molten metal relatively uniformly upon said end of said ingot by moving the point of deposition in a continuous rotary motion in a plane at approximately right angles to the longitudinal axis of said ingot and moving the center of said rotary motion in response to a determination of the temperature distribution around the periphery of the surface of deposition so as to maintain said temperature substantially uniform around said periphery.

3. In a method of producing metallic titanium by a reaction stream of a gaseous titanium halide and a gaseous reducing metal, the improvement comprising depositing said titanium relatively uniformly upon a surface of deposition by continuously directing the aforesaid reaction stream toward said surface of deposition while moving the point of initiation of said reaction stream in a continuous rotary motion in a plane approximately parallel to said surface of deposition and moving the center of said continuous rotary motion in response to a determination of the temperature distribution about the periphery of the surface of deposition so as to maintain the temperature substantially uniform around said periphery.

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