

# United States Patent [19]

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[54] **CONTROL APPARATUS FOR  
CONTINUOUSLY CASTING LIQUID METAL  
PRODUCED FROM CONSUMABLE  
ELECTRODES**

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[51] Int. Cl. .... **B22d 17/32**

[58] Field of Search .... **164/52, 252, 258, 155**

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[57] **ABSTRACT**

The melting rate of pre-alloyed consumable electrodes, melted in a controlled atmosphere, is selected and controlled to provide a desired freezing rate of a solidified billet delivered from a continuous casting machine. By controlling the power input to the electrode, the volume and temperature of metal melted and poured into the casting mold is also controlled to

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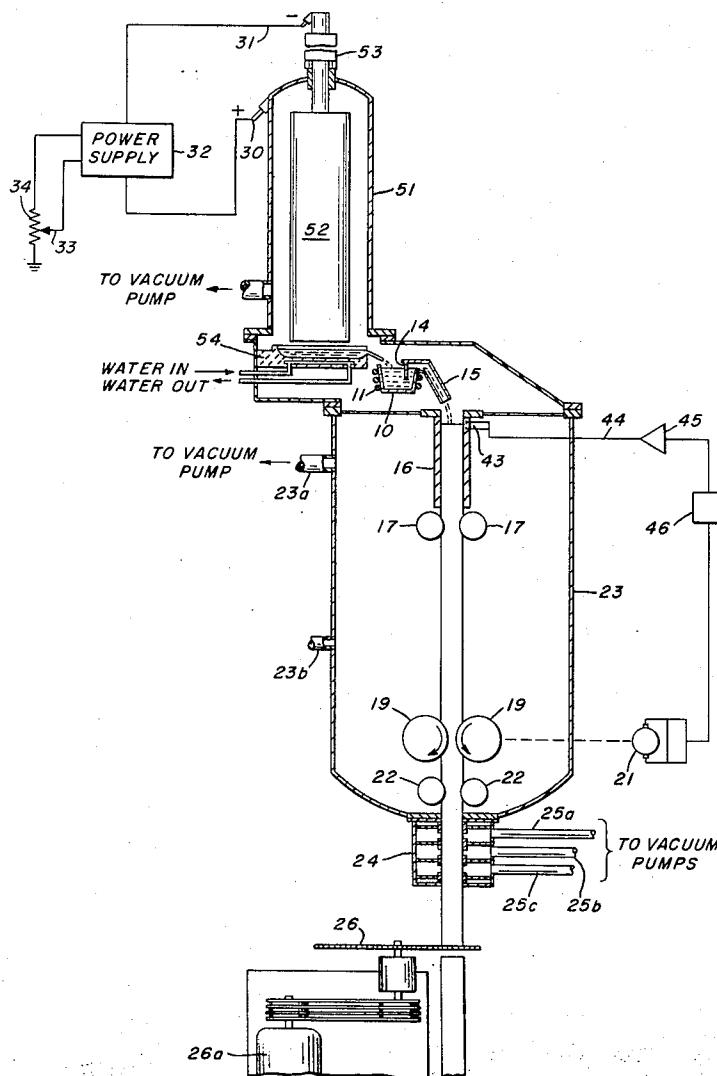
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## ABSTRACT

The melting rate of pre-alloyed consumable electrodes, melted in a controlled atmosphere, is selected and controlled to provide a desired freezing rate of a solidified billet delivered from a continuous casting machine. By controlling the power input to the electrode, the volume and temperature of metal melted and poured into the casting mold is also controlled to achieve a desired freezing rate and grain structure in the resulting ingot.

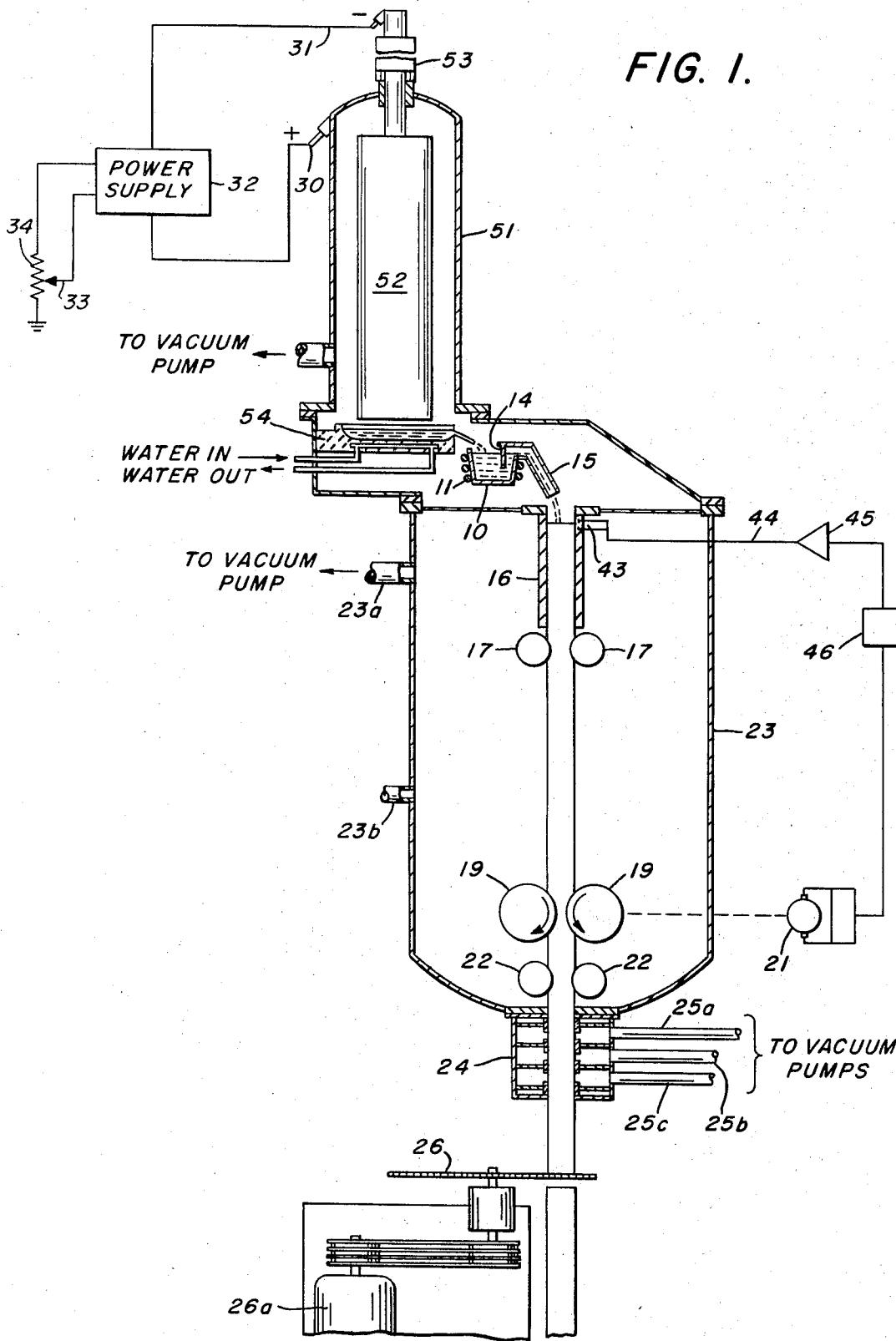
## 7 Claims, 3 Drawing Figures



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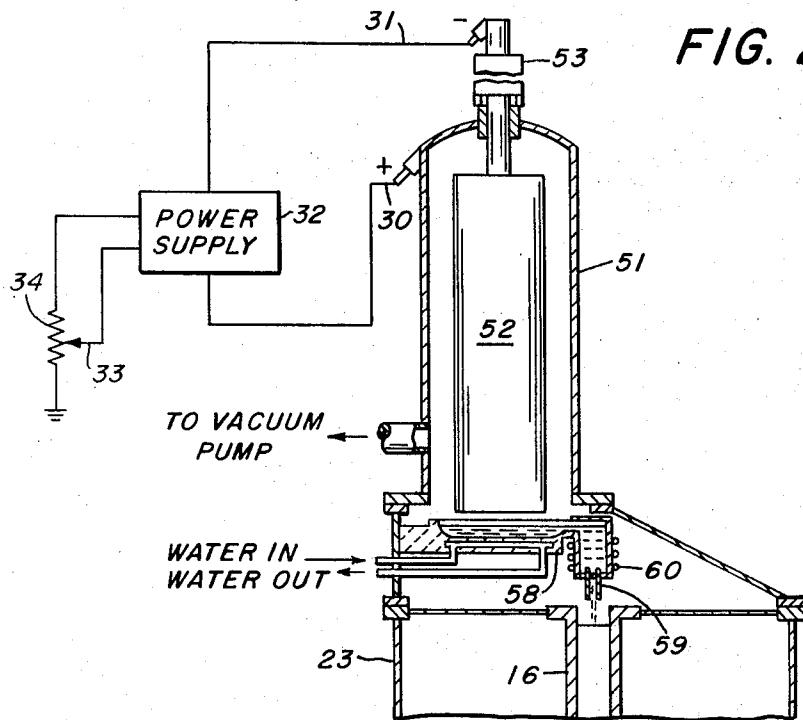
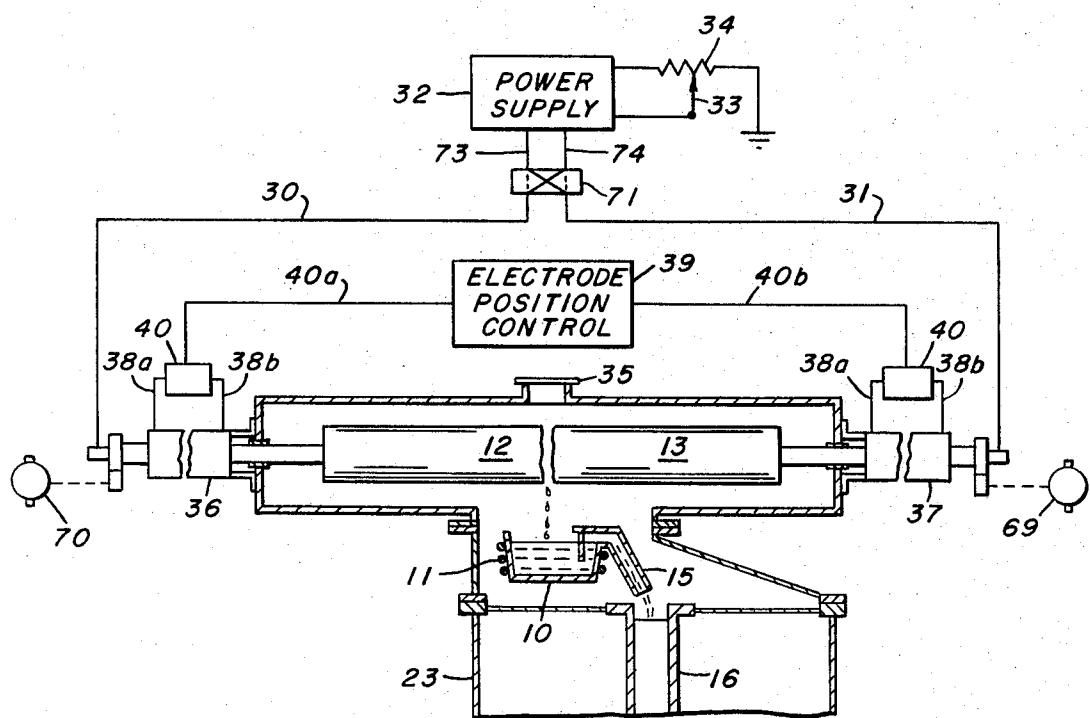


FIG. 3.



# CONTROL APPARATUS FOR CONTINUOUSLY CASTING LIQUID METAL PRODUCED FROM CONSUMABLE ELECTRODES

## BACKGROUND OF THE INVENTION

As is known, in the continuous casting process for ferrous alloys, molten metal from a tundish or the like is poured into a water-cooled mold, the resulting ingot formed upon cooling being pulled from the bottom of the mold continuously. As the molten metal comes into contact with the walls of the water-cooled mold, a thin solidified skin forms which usually separates from the mold wall shortly after solidification. As a result, most of the molten metal within the interior of the issuing casting solidifies after it leaves the watercooled mold. In order to effectively carry out the process of continuous casting of ferrous alloys, precise control of the temperature of the molten metal and the volume of metal poured into the mold is required. In a continuous casting process for carbon steels, for example, control of the temperature of the molten steel often requires the use of preheated ladles and a preheated tundish; however, with preheating and controls, the volume of metal poured into the mold and its temperature are extremely difficult to control, meaning that the freezing or solidification rate of the resulting casting is also difficult to control.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a controlled solidification rate of a continuously cast pre-alloyed metal supplied from a consumable electrode which is formed as an ingot of the pre-alloyed metal. The melting and casting processes are carried out in a controlled atmosphere, vacuum being the preferred means of controlling said atmosphere.

The method according to the present invention comprises the steps of providing an electrode from a metal ingot corresponding to the desired metallurgical composition of a billet to be continuously cast, striking an arc between the consumable electrode and a second electrode, controlling the melting rate by adjusting the power input to the electrodes on the basis of a desired solidification rate, providing a controlled atmosphere for the melting of the consumable electrode in a tundish in a given quantity to homogenize the metallurgical constituents of the liquid metal, continuously passing the homogenized metal from the tundish into an openended fluid cooled mold to partially solidify the metal and form a billet thereof, continuously withdrawing the partially solidified billet from the mold, further cooling the billet withdrawn from the mold, and discharging the solidified casting from within the controlled atmosphere. Additionally, there may be incorporated the step of severing the solidified casting into billets of predetermined length.

The control apparatus according to the present invention includes a power supply having control means for adjusting the power delivered to the electrodes for varying the rate of continuous melting of the consumable electrode. The apparatus further includes an electrode position control for maintaining a predetermined arc gap between the electrodes.

These features and advantages of the present invention, as well as others will be more readily understood

when the following description is read in light of the accompanying drawings, in which:

FIG. 1 is a schematic view of one embodiment of the present invention;

5 FIG. 2 is a second embodiment of the electrode melting apparatus for delivering liquid metal to the continuous casting apparatus shown in FIG. 1; and

FIG. 3 is a third embodiment of the electrode melting apparatus using two consumable electrodes.

With reference now to FIG. 1, there is provided a tundish 10 having a heating source (e.g., an induction coil 11 for preheating the tundish to prevent premature freezing of liquid metal passing into it from consumable electrode 52 and fluid cooled non-consumable stool 15.) The tundish also includes a skimmer wall 14 to prevent the outflow of slag or other impurities which may be floating on the metal surface in the tundish. A nozzle 15 directs the metal passing from the tundish into an open-ended continuous casting mold 16. The 10 mold includes walls which form water passageways for withdrawing heat from the liquid metal to form a partially solidified casting in the form of a billet. Other shapes and forms of casting may be provided through the use of different molds. As the outer skin of the casting 20 solidifies, it passes from the mold and between a pair of guide rolls 17 which provide support for the billet during its withdrawal from the mold. The billet is pulled downwardly by a pair of pinch rolls 19 which are driven by a motor 21. Downstream of the pinch rolls 25 there are provided additional guide rolls 22 which control the delivery of the casting from within a housing 23. The housing provides a non-reactive and protective atmosphere for the continuous casting apparatus as described thus far. A vacuum line 23a to evacuate housing 23 and an inert gas supply line 23b to provide an inert atmosphere for melting and solidification of the casting are connected to housing 23. Of course, either vacuum line 23a and/or inert gas supply line 23b could be used to provide the desired controlled atmosphere. 30 A dynamic seal 24 at the lower end of the housing 23 prevents contamination of the atmosphere within the housing. This seal incorporates a plurality of vacuum chambers each connected to a vacuum line (e.g., 25a, 25b and 25c, respectively). The billet casting may be 35 cut into desired billet lengths by a cut-off blade 26 driven by a motor 26a.

With reference now to the electrode 52, in the preferred form, this electrode is formed from an ingot of pre-alloyed metal corresponding in composition to that of the ultimate billets to be continuously cast. Below this electrode is a non-consumable fluid cooled stool 54. In this embodiment, the electrode and stool are connected by transmission lines 30 and 31, respectively, to a power supply 32 and a potentiometer 33 having a slide wire 34 manually set to vary the power delivered from the supply 32 to the electrode and the stool. The electrode 52 is contained within a chamber 51 within which it is supported vertically by means of support rod assembly 53. This support rod assembly 53 permits adjusting the position of the electrode to strike an arc on the non-consumable stool or electrode 54. In this specification and the appended claims, the term "electrode" means either a consumable or non-consumable electrode. As will be seen in some embodiments only one electrode is consumable; while in others both are consumable. As liquid metal droplets fall from the consumable electrode 52, they form a shallow

pool on the stool 54 from where the liquid metal flows into a preheated tundish 10. The tundish can be heated by electrical induction or resistance or other means 11. As the metal passes from the tundish, a skimmer wall 14 prevents the outflowing of slag or other impurities which may float upon the surface of the metal. The nozzle 15 directs the liquid metal into the upper end of the mold 16 wherein initial solidification of the casting occurs. The guide rolls 17 contact the casting as it is delivered from the mold. The billet travels downwardly through the pinch rolls 19, guide rolls 22 and through the dynamic seal 24. The power supply to the electrode and stool is controlled in a manner such that the volume of liquid metal which is poured into the casting mold is controlled to achieve the desired freezing rate and grain structure in the resulting casting. The entire system from chamber 51 through housing 23, including the intermediate segment surrounding tundish 10 and pouring nozzle 15, is enclosed and sealed, as shown, so as to provide a controlled atmosphere, e.g., vacuum or inert gas.

FIG. 2 illustrates the same embodiment of FIG. 1, except for a different pouring nozzle 59 which receives molten metal from stool 58 and directs the molten metal into mold 16. Pouring nozzle may be heated by means of the electrical resistance or induction coils 60. At least partial homogenization of the molten metal will occur in the pouring nozzle as in the tundish.

The use of the stool 54 in the embodiment of FIG. 1 and stool 58 according to the embodiment of FIG. 2 provides an immediate shallow pool area for collecting liquid metal droplets from the electrode. The depth of the pool is selected for optimum temperature of the metal flowing from the stool. This depth is usually less than one-third the diameter of the electrode 52.

Miniscus level control in the mold is governed by the withdrawal rolls 19 which are driven by a motor 21. The speed of this motor is controlled by a signal from a height sensing transducer 43 connected through conductor 44 to control amplifier 45 and servo system 46. As the melt rate changes, the miniscus level rises or falls within the mold; and the signal level from the liquid level transducer changes in proportion to the height. The speed of motor 21 is changed in accordance with the signal level in such a way as to maintain the miniscus height within predetermined limits.

With reference now to FIG. 3, an embodiment is shown which includes two consumable electrodes 12 and 13 in the preferred form. These electrodes are formed from ingots of prealloyed metal corresponding in composition to that of the ultimate billets to be continuously cast. The electrodes are connected by electrical transmission lines 30 and 31 respectively to a polarity reversing switch 71 and through other electrical transmission lines 73 and 74, respectively, to power supply 32. A potentiometer 33 having a slide wire 34 is manually set to vary the power delivered from the supply 32 to the electrodes. A sight glass 35 is provided in the housing for viewing the arc gap between the electrodes which are adjusted to continually maintain a predetermined arc gap by hydraulic drives 36 and 37. Lines 38a and 38b connect the hydraulic drives to a servo system 40 which is controlled by an electrode position control 39 through the lines 40a and 40b. Electrodes 12 and 13 are oscillated at least 180° about their axes in opposite directions by means of motors 69 and 70. Oscillation speed is controlled through a timer, not

shown, at a preset desired rate. An alternative to oscillation is the rotation of electrodes in opposite directions. However, at the present time oscillation has proven to be better.

The apparatus is placed in operation by adjusting the relative position of the consumable electrodes 12 and 13 through the operation of hydraulic drives 36 and 37 to obtain proper spacing for striking an electric arc. Current passes through the lines 30 and 31 in order to strike an arc and melt the electrodes. Proper spacing and centering of the electrodes is maintained by the electrode position control 39 as the electrodes are continuously consumed. The electrodes 12 and 13 are continually oscillated by means of motors 69 and 70 to insure uniform burnoff across the opposing faces of the electrodes during the melting process. The character of the arc is observed through the sight port 35. In order to further compensate for the problem of unequal burnoff rates of electrodes with opposite polarities, the polarities of the electrodes are preferably changed periodically by means of polarity reversing switch 71. Molten metal from the electrodes is collected to form a pool of liquid metal and homogenize it in tundish 10, which may be similar to that described in the embodiment of FIG. 1. The metal from tundish 10 flows under skimmer 14 and through nozzle 15 into the continuous casting mold 16. The remainder of the process is identical with that described in the embodiment of FIG. 1.

Although the invention has been shown in connection with certain specific embodiments, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

What is claimed is:

1. An apparatus for continuously casting prealloyed metal at a predetermined freezing rate to achieve a desired grain structure in the resulting casting, said apparatus comprising:
  - an enclosed chamber having a controlled atmosphere therein,
  - first and second electrodes forming a gap within said enclosed chamber for striking an arc therein, at least one of said electrodes being an ingot and the sole supply of pre-alloyed metal having a composition corresponding to the composition of a pre-alloyed continuous casting to be ultimately formed,
  - a power supply connected to said electrodes for melting the electrode of pre-alloyed metal,
  - electrode position control means including a drive for adjusting said gap to maintain an arc between said electrodes,
  - means spaced from said electrode of pre-alloyed metal for collecting liquid metal therefrom to form a homogeneous stream of molten metal within said enclosed chamber,
  - an open-ended fluid-cooled mold receiving a continuous stream of molten metal from said means for collecting liquid metal and partially solidifying the molten metal to continuously form a partially solidified casting,
  - adjustable control means to vary the power delivered by said power supply to said electrodes for controllably varying the rate of continuous melting of the pre-alloyed electrode on the basis of a predetermined solidification rate of the pre-alloyed metal

by said mold to form said pre-alloyed casting with a desired grain structure, and means for continuously withdrawing and solidifying the partially solidified casting from said mold for displacement from said chamber.

2. An apparatus according to claim 1 wherein said first electrode includes a consumable ingot of pre-alloyed metal, and said second electrode comprises a stool for collecting a pool of liquid metal from said ingot.

3. An apparatus according to claim 1 wherein said control means includes a potentiometer having an adjustable slide wire for selecting a desired melting rate.

4. An apparatus according to claim 3 wherein said electrode position control means receives an electrical

signal proportional to the delivery of power to said electrodes from said power supply.

5. An apparatus according to claim 1 further comprising means for producing an electrical signal proportional to the withdrawal speed of the solidified casting from said mold.

10 6. An apparatus according to claim 1 further comprising means for producing an electrical signal proportional to the height of molten metal in said open-ended fluid-cooled mold.

7. An apparatus according to claim 5 wherein said means for continuously withdrawing and solidifying a partially solidified casting includes a pair of pinch rolls, 15 and a motor for driving said pinch rolls.

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